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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 484
Contribution from the Bureau of Entomology, L. O. HOWARD, Chief
In cooperation with the Forest Service, HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER. April 9, 1917

CONTROL OF THE GIPSY MOTH BY FOREST MANAGEMENT

PART I: THE GIPSY MOTH IN WOODS

By G. E. CLEMENT, Assistant in Forest Management

PART II: MANAGEMENT OF TYPICAL WOODLOTS INFESTED WITH THE GIPSY MOTH IN THE WHITE-PINE REGION

By WILLIS MUNRO, Assistant in Forest Management

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

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INTRODUCTION.

The gipsy moth (*Porthetria dispar* L.) was first liberated in this country in 1868 or 1869, and 20 years later, about 1888, it became a very serious pest in the neighborhood in which it was liberated. Since then it has continued to spread, destroying both coniferous and deciduous foliage, until it is now found throughout a large part of eastern New England. (See map, p. 16.) It is particularly obnoxious because it feeds heavily on the foliage of so great a variety of trees and other forms of vegetation. Although many years have been spent in efforts to control the insect, it is still very abundant and in need of constant repression.

Trees may be classified as shade trees, fruit trees, and forest trees. Shade and fruit trees are more valuable, more accessible, and fewer in numbers than forest trees, and for these reasons have received much more attention than forest trees with respect to protection against gipsy-moth attack. Satisfactory means of protecting the first two classes of trees have been developed, but they are too expensive to be practicable in the case of forest trees. The problem of combating the gipsy moth in forests is a large one, and its solution will occupy many years.

Twenty years ago gipsy-moth caterpillars were reputed to be almost omnivorous. Studies made in more recent times by the

Bureau of Entomology have developed a number of important facts not formerly recognized. Among these are the following: (1) The foliage of some species of trees is more acceptable as food to gipsy-moth caterpillars than that of other species. (2) Caterpillars in the first stage of their development do not eat the foliage of conifers, except tamarack. These two facts apparently open up a considerable field for the use of forest management in the control of the insect.

Toward the end of the year 1912 Mr. W. F. Fiske, of the Bureau of Entomology, called attention to the gipsy moth as a forest insect and suggested the possibility of control by forest management.[1] In January, 1913, a cooperative agreement was entered into between the Bureau of Entomology and the Forest Service, providing for a full investigation of this matter. This investigation is now under way. It is based on the belief that infestation of woods can be reduced and possibly controlled by eliminating the species of trees which are particularly favored as food by gipsy-moth caterpillars and replacing such species with others which are less favored.

The object of the investigation is twofold. It is desired to ascertain in the first place in what proportions trees of different species can be associated to form stands which will not be subject to gipsy-moth ravages, and in the second place, the best method of converting existing stands into others better able to resist attack.

The plan for the work of this investigation provides for the establishment of sample plots in different kinds of typical forest stands in the infested region. Stands varying in composition, quality, age, climatic situation, and degree of gipsy-moth infestation are to be subjected to different forms of management with a view to determine what forms produce the safest stands and the best methods of establishing the most favorable conditions. During the past three years 46 sample plots have been established, and much of the prescribed work has been done on them. Several years must elapse before conclusions can be drawn from these experiments.

In the course of carrying out the work just referred to a number of facts have been observed, and it is believed that a presentation of these facts may be of interest.

BEHAVIOR OF THE GIPSY MOTH IN THE WOODS.

The gipsy moth may be introduced into forests by the wind,[2] by caterpillars crawling from adjacent infested areas, or by transportation by man or animals.[3] The caterpillars begin feeding as soon as the new foliage appears in the spring and stop before the middle of July. A gipsy-moth colony may exist for several years in a wood without doing sufficient damage to attract any attention. The members of such a colony multiply in numbers continuously and spread over more and more territory until ultimately a point is reached where the caterpillars suddenly become so abundant that they defoliate large numbers of trees, frequently over wide areas.

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[1] Fiske, W. F. The Gipsy Moth as a Forest Insect, U. S. Dept. Agr. Bur. Ent. Circ. 164. 20 p. 1913.

[2] Collins, C. W. Dispersion of Gipsy Moth Larvæ by the Wind, U. S. Dept. Agr. Bul. 273. 23 p., 6 pl., 1 map. 1915.

[3] Burgess, A. F. The Dispersion of the Gipsy Moth, U. S. Dept. Agr. Bur. Ent., Bul. 119. 62 p., 6 fig., 16 pl., map. 1913.

Following a gipsy-moth defoliation over a considerable area, the intensity of an infestation generally diminishes. This is due largely to the following causes: (1) Caterpillars die of starvation or migrate on account of the exhaustion of their food supply. (2) An epidemic of the wilt disease destroys large numbers of the insects. (3) Natural enemies, particularly parasites and predacious beetles, reduce the infestation.

Woods which have suffered a heavy gipsy-moth attack are thus usually provided with some opportunity to recover. A few caterpillars survive in such cases, and in the course of a few years (three to five) defoliation again occurs. There is usually very heavy feeding following a season of defoliation if it happens, as it may occasionally, that an infestation is of such an extent that the amount of foliage available is just sufficient to carry the caterpillars to the pupation stage.

An infestation once established in a wood will probably remain as long as the food supply lasts, but the degree of infestation will vary from time to time.

The development and extent of gipsy-moth infestations are influenced to a large degree by meteorological conditions, insect enemies, and the wilt disease. Owing to the uncertainty with which these factors act, it is impossible to make a definite prediction as to the exact outcome of any infestation.

Feeding occurs in varying degrees over all the infested region, the extent in any locality depending on the stage of the infestation and the character of the food. After defoliation most trees immediately put forth new foliage, and in a few weeks there is usually but little external evidence of damage. In such cases the injury amounts only to a temporary retardation of development, and from this the trees attacked usually recover. Trees previously weakened through the action of decay, fire, or poor growing conditions may not survive one defoliation, but mortality through this cause is low.

Gipsy-moth feeding does not cease until after most of the early summer rains have fallen, so that defoliated trees in their weakened condition encounter more or less unfavorable conditions for their recovery. An unusually dry summer may influence recovery very adversely. Defoliation by gipsy-moth caterpillars usually occurs when the larvæ are in the very last stages, but occasionally defoliation is effected by caterpillars in earlier stages, in which case the defoliated trees have a better chance to recover, because there remains a longer period than usual in which they may grow and recuperate.

Repeated defoliation from year to year will ultimately kill any tree or render it susceptible to the attacks of bark borers, which produce the same result. In the gipsy-moth region repeated annual defoliation may result from the combined activities of the gipsy moth, brown-tail moth (*Euproctis chrysorrhoea* L.), forest tent caterpillar (*Malacosoma disstria* Hübn.), and several other common species. Thus, at times when gipsy moths are not abundant, trees previously stripped of foliage by them would doubtless often recover were it not for the activities of other defoliators. Brown-tail moth larvæ cease feeding not later than the middle of June, so that defoliated trees have the advantage of a part of the spring precipitation, and more time to recuperate before the end of the growing season.

Oaks have suffered the highest mortality among defoliated forest trees, probably because of the action of the two-lined chestnut borer (*Agrilus bilineatus* Weber), whose work is usually present beneath the bark of all dead specimens. Many defoliated oaks which have died would doubtless have recovered had it not been for the additional injury produced by this borer. Oaks, more than any other species, are found growing in unfavorable situations in the infested region, which, together with the fact that the infested region includes the northern limit of the range of the white oak, is responsible for many oaks of poor physical condition. Trees in poor condition are particularly liable to serious damage by defoliation, especially in connection with attack by the two-lined chestnut borer, which infests only weakened trees. The removal of dying oaks would not only help to reduce a gipsy-moth infestation, but would reduce the numbers of Agrilus and create room for species of trees for which the situation is more favorable.

COMPOSITION AND CONDITION OF WOODS IN INFESTED TERRITORY.

At present the gipsy-moth infestation is largely confined to what Hawley and Hawes[1] have designated the White-pine Region. The northern part of the infested region in Maine and New Hampshire extends a little into the "Northern Hardwoods Region," and the infested portions of Rhode Island and Connecticut lie in the "Sprout Hardwoods Region."

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[1] Hawley, R. C., and Hawes, A. F., Forestry in New England; a Handbook of Eastern Forest Management. New York, 1912. 479 p. (P. 196.)

The White-Pine Region is broadly characterized by stands of (1) pure white pine, (2) mixed white pine and hardwoods, and (3) mixed hardwoods. The predominating hardwoods in this region are the oaks. Other hardwoods are birches, beech, maples, hickories, ashes, poplars, and chestnut. Pitch pine occurs in pure stands over certain small portions.

The Northern Hardwoods Region is characterized by stands of maples, beech, and birches. The sugar maple, beech, and yellow birch are particularly characteristic. Spruce, white pine, and hemlock also occur in the region, together with red oak, white ash, black ash, black cherry, paper birch, and basswood.

The Sprout Hardwoods Region is characterized by stands of chestnut, either pure or in mixture with several species of oak. Other hardwoods occurring in this region are maples, ashes, birches, poplars, tulip, and hickories.

The stands in all three of the regions vary greatly in composition and are frequently very complex. This is largely due to the usual methods of lumbering and to the repeated action of fire. Stands have been repeatedly culled or cut clear with no provision for reproduction. This system and repeated fires have been responsible in many cases for the extensive introduction of species which would otherwise be absent or be represented by only a few individuals.

A large amount of neglected pasture and cultivated land in New England is reverting to woods. The trees which generally spring up on such lands are white pine, gray birch, red cedar, poplar, pin cherry, and, in places, red maple. The stands thus derived are usually very open for a long period of time, and the quality, aside from the composition, is therefore poor.

Large blocks of woodland under single ownership are rather scarce, and the woods for the most part occur on more or less isolated small lots belonging to many different owners. Owing to this fact and to the great diversity in the composition of woods, even on small areas, it is impossible to classify the stands of timber growing in the infested region except in a very general way.

The complexity and variable composition of the woods in the region infested by the gipsy moth are indicated by the table (p. 6). This shows the composition of the stands on some of the areas used for experimental work, and the trees are only the living ones which are two and a half inches in diameter and over at breast height.

Complexity and variable composition of woods in the area infested by the gipsy moth.

1 acre in Dover, Mass. Mixed hardwoods.

Species:	*Per cent.*
Red oak	45
White oak	38
Black oak	11
White pine	3
Red maple	(1)
Gray birch	(1)
Pignut hickory	(1)
White ash	(1)
	100

2½ acres in Exeter, N. H. Mixed hardwoods.

Species:	*Per cent*
Red oak	31
White oak	30
Black oak	26
Red maple	7
White pine	4
Gray birch	(1)
Pignut hickory	(1)
Black birch	(1)
Beech	(1)
Pitch pine	(1)
Yellow birch	(1)
Aspen	(1)
Black cherry	(1)
Elm (American)	(1)
Apple	(1)
	100

5.4 acres in Wareham, Mass. Mixed hardwoods.

Species:	*Per cent.*
Scarlet oak	54
White oak	21
White pine	15
Black oak	8
Pitch pine	1
Red oak	(1)
Red maple	(1)
Gray birch	(1)
Black gum	(1)
	100

1.3 acres in Medfield, Mass. Mixed hardwoods.

Species:	*Per cent.*
Chestnut	52
Red oak	21
White oak	10
White pine	9
Black oak	7
Red maple	1
	100

4.2 acres in Amesbury, Mass. White pine and mixed hardwoods (old-field growth).

Species:	*Per cent.*
White pine	28
Gray birch	21
Black oak	16
Red maple	10
Pitch pine	8
White oak	5
Red cedar	5
White ash	2
Swamp white oak	1
Chestnut	(1)
Red oak	(1)
Black birch	(1)
Pignut hickory	(1)
Butternut	(1)
Aspen	(1)
Wild red cherry	(1)
American elm	(1)
Hop hornbeam	(1)
Apple	(1)
	100

3.4 acres in North Berwick, Me. Northern hardwoods.

Species:	*Per cent.*
Beech	45
Hop hornbeam	16
Sugar maple	14
Red maple	8
Black birch	4
Hemlock	4
Yellow birch	3
Red oak	2
Paper birch	2
White ash	1
Big-tooth poplar	(1)
Basswood	1
American elm	(1)
Black ash	(1)
	100

11 acres in Westbrook, Me. White pine and mixed hardwoods.

Species:	*Per cent.*
White pine	23
Red oak	21
Gray birch	20
Red maple	16
Hemlock	7
Paper birch	3
Shagbark hickory	2
Balsam fir	1
White ash	1
Big-tooth poplar	1
Choke cherry	1
Hop hornbeam	1
Pitch pine	(1)
Chestnut	(1)
Black oak	(1)
Sugar maple	(1)
Beech	(1)
	100

[1] Less than 1 per cent.

The physical condition of the trees composing the woods in the infested region is extremely poor, due largely to the action of repeated fires which destroy the litter and decomposed vegetable matter so essential to successful tree growth. Fire is also responsible for physical injury to trees and the admission through fire wounds of injurious fungi and insect borers. A very high percentage of the deciduous trees in the infested region is of sprout origin. The stools from which these have sprung are often worn out and more or less decayed, and from such impaired stock it is unreasonable to expect successful tree growth.

Owing to poor physical condition, small size, and limited proportion of desirable species, the woods of the infested region are of relatively low commercial value. Under present conditions a large quantity of the white pine is suitable only for box boards, and a large portion, possibly 75 per cent, of the deciduous growth is suitable only for fuel.

The composition and physical condition of woods subject to gipsy-moth infestation have a very important bearing on the extent of the damage which may ensue therefrom. Coniferous trees grown in pure stands are immune from any considerable damage. The ashes are seldom attacked, and the red maple, sugar maple, hickories, and chestnut are not seriously affected. The proportions of such species occurring in stands have considerable influence upon the degree of damage done. Trees weakened by drought, fungi, fire, suppression, or other unfavorable growing conditions can offer only a weak resistance to the effects of defoliation and so are much more likely to succumb than vigorous trees.

The presence of dying and weakened trees in a wood is very objectionable, inasmuch as such trees harbor injurious borers, and these multiply rapidly when favorable conditions for their entrance into other trees are provided by defoliation.

The forests of the infested region are highly valued for their attractiveness and the protection they afford. There is probably no region in which the esthetic features of woods are more valued than in New England, and there are numerous instances where they are maintained largely out of consideration for their appearance. Woods thus maintained are generally of better quality than others, but there is usually a chance to increase the commercial value of many such stands. Such improvement would not impair esthetic values.

It is quite impossible to appraise the damage inflicted upon owners of woods by gipsy moths. The woods vary so much in composition and quality, and individual trees suffer in such varying degree, that there is no available basis for such an estimate. The esthetic value which an owner or community places upon woods adds to the difficulty of such an appraisal. Individuals and communities have frequently gone to large expense to protect inferior stands of timber against the ravages of the gipsy moth, and in such cases the reduction of infestations is of greater importance than the conservation of the woods alone, since adjoining fruit and shade trees are thereby protected.

The scarcity and corresponding values of forest products of good quality in New England appear to justify an outlay in improvement measures. Trees capable of producing only material of low value should be removed and replaced by more valuable species. Defective and dying individuals should be made to give way to vigorous trees. Trees growing on sites on which other species will yield greater values should be replaced by such species. The complexity of many stands should be greatly reduced, for it is a very difficult matter to grow together successfully a large variety of trees varying widely in their requirements.

The expense necessary to bring about the desirable changes would be the following: (1) The sale of a lower grade, and hence a less profitable product than would be available under present methods. (2) Added expense of cutting, owing to the greater cost of cutting scattered trees instead of cutting clear. (3) Added expense of cutting, owing to the effort which should be made to protect young growth of desirable species already started on the ground. (4) The cost of planting desirable species where these can not be procured by natural seeding.

FEEDING HABITS OF GIPSY-MOTH CATERPILLARS.

The Bureau of Entomology has conducted extensive experiments to ascertain the feeding habits of the gipsy moth. The methods used and the results obtained have been described by Mosher.[1] The results of these experiments have considerable bearing on any forest management which may be prescribed in an effort to control infestations in woods.

Mosher has classified the trees and shrubs of the region according to susceptibility to gipsy-moth attack. This classification includes several species of trees which are not indigenous and some which occur almost exclusively as ornamental trees. Following is a list of only the indigenous and naturalized forest trees of the region as classified by Mosher. The nomenclature used here is that which has been adopted as standard by the Forest Service. It varies slightly from that used in Bulletin No. 250.

Class I: Species that are favored food of the gipsy-moth larvæ in all their stages.

Ash, Mountain (*Sorbus americana* Marsh.).
Aspen (*Populus tremuloides* Michx.).
Aspen, Large-tooth (*Populus grandidentata* Michx.).
Balm of Gilead (*Populus balsamifera* Linn.).
Basswood (*Tilia americana* Linn.).
Beech (*Fagus atropunicea* [Marsh.] Sudw.).
Birch, Gray (*Betula populifolia* Marsh.).
Birch, Paper (*Betula papyrifera* Marsh.).
Birch, River (*Betula nigra* Linn.).
Boxelder (*Acer negundo* Linn.).
Oak, Black (*Quercus velutina* Lam.).
Oak, Bur (*Quercus macrocarpa* Michx.).
Oak, Chestnut (*Quercus prinus* Linn.).
Oak, Pin (*Quercus palustris* Muench.).
Oak, Post (*Quercus minor* [Marsh.] Sargent).

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[1] Mosher, F. H. Food Plants of the Gipsy Moth in America, U. S. Dept. Agr. Bul. 250. 39 p., 6 pl. 1915.

Oak, Red (*Quercus rubra* Linn.).
Oak, Scarlet (*Quercus coccinea* Muench.).
Oak, Scrub (*Quercus pumila* [Marsh.] Sudw.).
Oak, Swamp white (*Quercus platanoides* [Lam.] Sudw.).
Oak, White (*Quercus alba* Linn.).
Service Berry (*Amelanchier canadensis* [Linn.] Medic.).
Sumac, Dwarf (*Rhus copallina* Linn.).
Sumac, Staghorn (*Rhus hirta* [Linn.] Sudw.).
Tamarack (*Larix laricina* [Du Roi] Koch.).
Willow, Glaucous (*Salix discolor* Muehl.).
Witch Hazel (*Hamamelis virginiana* Linn.).

Class II: Species that are favored food for gipsy-moth larvæ after the earlier larval stages.

Chestnut (*Castanea dentata* [Marsh.] Borkh.).
Hemlock (*Tsuga canadensis* [Linn.] Carr.).
Pine, Pitch (*Pinus rigida* Mill.).
Pine, Red (*Pinus resinosa* Ait.).
Pine, White (*Pinus strobus* Linn.).
Spruce, Black (*Picea mariana* [Mill.] B. S. P.).
Spruce, Red (*Picea rubens* Sargent.).
Spruce, White (*Picea canadensis* [Mill.] B. S. P.).

Class III: Species that are not particularly favored, but upon which a small proportion of the gipsy-moth larvæ may develop.

Beech, Blue (*Carpinus caroliniana* Walt.).
Birch, Black (*Betula lenta* Linn.).
Birch, Yellow (*Betula lutea* Michx.f.).
Cherry, Black (*Prunus serotina* Ehrh.).
Cherry, Choke (*Prunus virginiana* Linn.).
Cherry, Wild Red (*Prunus pennsylvanica* Linn.f.).
Cottonwood (*Populus deltoides* Marsh.).
Elm, American (*Ulmus americana* Linn.).
Elm, Slippery (*Ulmus pubescens* Walt.).
Gum, Black (*Nyssa sylvatica* Marsh.).
Hickory, Bitternut (*Hicoria minima* [Marsh.] Britton).
Hickory, Mocker-nut (*Hicoria alba* [Linn.] Britton).
Hickory, Pignut (*Hicoria glabra* [Mill.] Britton.).
Hickory, Shagbark (*Hicoria ovata* [Mill.] Britton).
Hop Hornbeam (*Ostrya virginiana* [Mill.] Koch.).
Maple, Red (*Acer rubrum* Linn.).
Maple, Silver (*Acer saccharinum* Linn.).
Maple, Sugar (*Acer saccharum* Marsh.).
Poplar, Silver (*Populus alba* Linn.).
Sassafras (*Sassafras sassafras* [Linn.] Karst.).

Class IV: Species that are unfavored food for gipsy-moth larvæ.

Arborvitæ (*Thuja occidentalis* Linn.).
Ash, Black (*Fraxinus nigra* Marsh.).
Ash, Red (*Fraxinus pennsylvanica* Marsh.).
Ash, White (*Fraxinus americana* Linn.).
Balsam Fir (*Abies balsamea* [Linn.] Mill.).
Butternut (*Juglans cinerea* Linn.).
Cedar, Red (*Juniperus virginiana* Linn.).
Cedar, White (*Chamaecyparis thyoides* [Linn.] B. S. P.).
Dogwood, Flowering (*Cornus florida* Linn.).

Hackberry (*Celtis occidentalis* Linn.).
Holly, American (*Ilex opaca* Ait.).
Laurel, Mountain (*Kalmia latifolia* Linn.).
Locust, Black (*Robinia pseudacacia* Linn.)
Locust, Honey (*Gleditsia triacanthos* Linn.).
Maple, Mountain (*Acer spicatum* Lam.).
Maple, Striped (*Acer pennsylvanicum* Linn.).
Mulberry, Red (*Morus rubra* Linn.).
Sheepberry (*Viburnum lentago* Linn.).
Sycamore (*Platanus occidentalis* Linn.)
Tulip (*Liriodendron tulipifera* Linn.).
Walnut, Black (*Juglans nigra* Linn.).

Shrubs occur frequently as undergrowth in the woods of the infested region and may have an important bearing on the infestation of the trees growing above or around them. A stand of such species of trees as are not fed upon until the larvæ reach their later stages might be immune from damage were it not that the larvæ are enabled to reach these later stages by feeding on near-by shrubs. Most of the shrubs which grow in the region die out if sufficiently shaded, and the balance occur so rarely in shade or are eaten to such a slight degree by gipsy-moth larvæ that they are unimportant. If forests were under management the danger of woods thus being infested would be eliminated, because in a properly managed forest the trees should be so grown that they produce at all times an amount of shade sufficient to preclude the development of shrubs in any numbers.

Larvæ feeding on shrubs which are favored food plants, occurring in open land adjacent to woods, might migrate to the woods, but would not penetrate very far if the trees of the stands were of any but those of Class I.

The following statement appears on page 27 of Bulletin 250: "There is in some cases, at least, considerable variation in susceptibility of different trees of the same species." This should be considered carefully in connection with any form of management which prescribes the removal of certain trees on the ground that they are liable to infestation.

PRECAUTIONS NEEDED.

Natural enemies of the gipsy moth, in particular those introduced from abroad, are constantly increasing in numbers, and their influence is a large factor in the control of the moths in woods. It is safe to assume that this increase in numbers is going to continue and that in the future the character of gipsy-moth damage to woods will thereby be greatly modified.

In view of the above, and of the fact that it is impossible definitely to predict the outcome of an infestation under any circumstances, it is unwise to attempt to eliminate any particular species out of consideration for susceptibility to gipsy-moth attack alone. There is sufficient cause for removing many trees on the ground that they are mature, dying, defective, unfavorably situated, or interfering with the development of better trees. It is not good forest policy to remove any thrifty young tree until it has been given every opportunity to yield a return on the investment which it represents. To remove such young trees would be similar to abandoning a crop of young potato plants because of the appearance of the potato beetle.

Sawmill men have frequently induced owners to sell standing white pine by asserting that the trees were doomed to destruction by the presence of the gipsy moth. An owner believing this is likely to be induced to sell his stumpage at whatever price the sawmill man may choose to offer him. This practice has resulted in the cutting of immature trees which would have yielded a greater profit to the owner if permitted to mature. *No owner who is unfamiliar with the action of the gipsy moth in woods should permit himself to be influenced by a timber buyer to part with thrifty trees of any sort on the ground that the trees are liable to attack by gipsy moths. The advice of State and Federal officers who are familiar with the problem is available to any owner of woods in the region.*

The poor condition of woods, combined with the damaging effect of gipsy-moth attack, makes improvement and protective measures imperative. Introduced enemies of the gipsy moth are becoming well established and are doing effective work, and the wilt disease prevails throughout the region.[1] Still the woods continue to be defoliated by gipsy moths, and further protective measures are in demand.

Any plan for the silvicultural improvement of stands of trees should provide for the removal of dead, dying, mature, and defective trees, trees standing in unfavorable situations, and trees of low commercial value. It should provide for the replacement of these removed trees with thrifty trees of high commercial value well adapted to their environment. It should also provide for a compact stand of trees without overcrowding. Such action alone would constitute a protective measure of great value, but if it could be extended to embrace the removal of trees and conditions favorable to the development of the gipsy moth and the replacement of these by trees and conditions unfavorable to the gipsy moth, a still greater degree of protection would be provided.

APPLICATION OF FOOD-PLANT DATA TO INDIVIDUAL SPECIES.

The classification of trees on the basis of the extent to which they are fed upon by gipsy moths (p. 8–10) is one which may well be used in the production of stands of trees which shall be free from gipsy-moth damage. A detailed consideration of the classification in this light is interesting and may prove of value in combining protective with improvement measures.

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[1] Glaser, R. W. Wilt of gipsy moth caterpillars. *In* U. S. Dept. Agr. Jour. Agr. Res., v. 4. No. 2, p. 101–128, 17 fig., May 15, 1915. (P. 102.)

Class I (p. 8) is composed of 26 species which are favored food of gipsy-moth larvæ. Ten of these species, mountain ash, gray birch, river birch, boxelder, scrub oak, service berry, dwarf sumac, staghorn sumac, glaucous willow, and witch hazel, yield products of low commercial value and should in any case be eliminated from mixed woods.

Ten of the species in this class are oaks, including the scrub oak just referred to. All oaks require the best of forest soils to develop well and profitably. Oaks growing on thin soils, rocky ridges, and very sandy soil are usually not very vigorous and frequently suffer severely from gipsy-moth attack. If oaks were removed from the unfavorable sites on which they very often occur and were confined to sites best adapted to their requirements, a large amount of gipsy-moth food would be eliminated, a better quality of oak would be produced, and there would be available a considerable acreage of forest land better suited to the growth of other valuable trees.

The bur oak, chestnut oak, pin oak, post oak, and swamp white oak are generally more or less rare and of restricted local occurrence in the infested region. On account of their scattered distribution they are not of any great commercial importance here. In consideration of their susceptibility to moth attack and capacity for maintaining infestations, they could well be spared from most stands in which they occur.

The white oak reaches the northern limit of its range in the infested region, but still is one of the most abundant of the oaks. This abundance is abnormal and is due to the sprouting capacity of the species, resistance to the effect of fire, and current methods of cutting. The trees grow very slowly and seem to be particularly favored by both gipsy and brown-tail moths. A very large proportion of the existing trees of this species could be removed to great advantage.

The red oak, black oak, and scarlet oak do well in the infested region, and it is hoped that the experiments now under way will show that there may be conditions under which they may be safely grown.

The following poplars occur in Class I: Aspen, large-tooth aspen, and balm of Gilead. These species all demand a large amount of light and occur only where it can be procured. As a result they generally occur scattered in mixed woods, and pure where they can get the necessary start. They grow rapidly, and when they occur in any abundance are in good demand for excelsior and pulp manufacture. There is some question as to what extent they should be encouraged in view of their susceptibility to gipsy-moth attack.

Basswood occurs very much scattered in the infested region. It grows to advantage only on the best sites and should be eliminated from all others.

Beech occurs most abundantly in the northern portion of the region. It grows slowly and is liable to become defective before maturity. It is perhaps the least liable to damage of any Class I trees.

Paper birch demands a great deal of light and is not abundant in mixed stands. Where it occurs in abundance it is in great demand for spool and novelty wood. Scattered specimens may be replaced with species which are less liable to gipsy-moth attack.

Tamarack is nowhere abundant in the infested region. It is a tree which can well be cut out when found outside of pure stands. It is the only conifer which is eaten by the youngest gipsy-moth larvæ.

Class II (p. 9) is composed of eight species of trees on which gipsy-moth caterpillars in their earliest stages do not feed, but upon which they do feed in their later stages. Young caterpillars must have food, and if this is not available they can not attain the point in their development where they can feed on the trees of this class. Hence if stands of these trees have in their vicinity no plants upon which the young caterpillars can feed, the stands are practically immune from attack. Trees of this class can therefore be safely grown in pure stands, in mixture, where conditions permit, with one another, or in mixture with Class IV trees.

Stands composed largely of one or more of the species of this class can be made immune from gipsy-moth attack by removing the plants which may provide young larvæ with food. Since most of the species which are susceptible to gipsy-moth attack are deciduous, provision in this case will have to be made for the suppression of the sprouts which follow cutting.

Trees of this class may be substituted frequently for removed trees of species susceptible to moth attack. The white pine is particularly important in this respect, owing to its commercial value, rapidity of growth, and adaptability to a variety of sites. The red pine, while somewhat slower growing and of slightly less value, is also a valuable tree and deserves particular consideration owing to its immunity from the white-pine blister rust.

Chestnut is the only deciduous tree of this class. It grows well and yields a valuable product, but unfortunately is subject to attacks of the chestnut blight. In the light of existing conditions the propagation of this species can not be advocated.

Class III (p. 9) is composed of 20 species which are not particularly favored, but upon which a small proportion of gipsy-moth larvæ may develop. Stands composed of any trees of this class and containing none of the trees of Class I would maintain slight infestations and would rarely, if ever, be defoliated.

Blue beech, choke cherry, wild red cherry, hop hornbeam, and sassafras have no particular commercial value, and the elimination of these species from stands would afford some degree of protection.

Black cherry has considerable commercial value, but occurs very scatteringly. As it is not a favored food, it may well be left in view of its value. American elm and slippery elm also occur as scattered trees. Their value is less than black cherry, but they might well be left. Cottonwood, bitternut hickory, black gum, silver maple, and silver poplar if found might well be eliminated from most stands. Such an elimination would help to reduce the complexity of stands and would serve as a protective measure.

The remaining species of this class, black and yellow birch, mockernut, pignut and shagbark hickories, and red and sugar maple, can be grown in comparative safety. In any process of gradual transformation these species should be retained in preference to the trees of Class I.

Class IV (p. 9) is composed of trees on which the gipsy moth does not feed, or if it does, the amount is so slight as to be entirely negligible. Stands composed of trees of this class alone, or combined with the trees of Class II, need cause no anxiety whatever as far as gipsy-moth attack is concerned. Some of the species of this class are of rare occurrence, some require peculiar conditions for their development, and some have little or no commercial value. Arborvitæ, black ash, and white cedar require very moist situations and usually occur in or near swamps. Butternut, red cedar, locust, honey locust, and sycamore all require a large amount of light. The red ash, hackberry, American holly, red mulberry, tulip, and black walnut are of rare and local occurrence, for which reason they can not be depended upon to supply any large commercial demand. Flowering dogwood, mountain laurel, mountain maple, striped maple, and sheepberry have little or no commercial value locally. The white ash has a high commercial value, but should be confined to the best forest soils.

In general, it may be said that stands containing only trees of Classes II, III, and IV will suffer but slight damage from gipsy-moth attack. The number of Class I trees would be tremendously reduced if the worthless species were replaced by suitable trees and the remainder were confined to the best sites, as is necessary if they are to be grown at all profitably.

Any plan for the removal of trees must provide for their replacement with more desirable ones. All trees may be removed in one operation and replaced in another, or the transformation may be gradual. There are many conditions which influence the methods to be employed, and these vary greatly among different stands. It is hoped that the experiments now in operation will provide a basis for definite recommendation as to the best methods to be employed under some of the most characteristic conditions.

Forest management requires a relatively long time to produce results and necessitates a considerable investment. For these reasons a definite object and plan of action are essential to success. In a large majority of cases the primary object is to produce a valuable crop of timber. The object must be decided by the owner, but methods to be employed require the knowledge of a forester, since the values and habits of different species of trees and the character of soils must be known and should have expert consideration.

OTHER MEASURES IN NEED OF ATTENTION.

There is a need of a wide application of any steps adopted to control the gipsy moth in woods. The efforts of scattered individual owners may be offset by the indifference of neighboring owners on whose properties the moths are permitted to increase without interruption. On account of the greatly divided ownership of woodland in the infested region, this amounts to a considerable obstacle. There is great need of impressing upon owners the necessity of concerted action in the improvement and protection of their woods. How this can be accomplished is a problem to which immediate attention should be given.

The woods of New England have reached their present stage of degeneracy through a long period of abuse and neglect, and it will take years to restore them. Owing to the nature of the ownership of our woods and present economic conditions restorative measures must be simple and practicable for all owners. More good will be accomplished by the universal adoption of simple but definite improvement measures than by the sporadic application of intensive measures. As soon as the value of such a beginning has been demonstrated owners will be ready enough to adopt further measures, and by that time these will be better justified by economic conditions. Improvements necessitate the investment of money, and the value of such improvements must be demonstrated before they will be generally adopted. One of the greatest needs among New England wood owners is that they may be impressed individually with the necessity and desirability of starting some definite, if simple, improvement measures at once.

The difficulty of securing concerted action upon protective measures against the gipsy moth has directed attention to the question of town forests, one which is now being agitated to some extent in New England. Town forests would provide areas of considerable size upon which systematic control measures could be put into operation with assurance of a fair trial. Such conditions would be most favorable to the solution of such a problem as the one under consideration. Furthermore, town forests would supply other benefits, among which the following may be mentioned: (1) Large areas of waste land could be made to yield an income. (2) Communities would be provided with a permanent local supply of wood products, the use of which for manufacturing purposes would insure a certain amount of local industrial activity. (3) Private owners would be supplied with examples of the value of systematic management. (4) Communities would have convenient recreation grounds of the most desirable sort. (5) An opportunity would be given to begin now to establish forests of quality to meet future needs. Most individual owners lack the means or the desire to adopt such a policy, although everyone realizes the need of such measures.

The low commercial value of most of the trees suggested for removal and the cost of restocking land with new trees combine to prohibit in many instances the adoption of obviously desirable improvement and protective measures. A vigorous effort should be made to stimulate the existing market for inferior hardwoods and to discover new uses for such woods. If an active demand for low-grade hardwoods could be created, the problem of controlling the gipsy moth in woods would be much easier than under present conditions.

RECOMMENDATIONS.

The following recommendations are made in the belief that their adoption would be of great value in the solution of the problem of the control of the gipsy moth in woods. It is therefore recommended:

(1) That steps be taken to impress on every individual woodland owner the desirability of adopting and practicing simple but definite improvement and protective measures. (2) That the following suggestions be carefully considered by woodland owners who wish to improve and protect their woods:

(*a*) Cut all trees designated as of low commercial value in Class I when they are shading or in any way interfering with the growth and development of trees in Classes II, III, and IV.

(*b*) Cut all species indicated as being of low commercial value in Classes III and IV when they are in any way interfering with the growth of valuable species in the same classes.

(*c*) Cut as soon as possible all trees which have started to die. Dying trees often breed very injurious borers.

(*d*) Cut no thrifty trees merely out of fear that they will be attacked by insects, excepting in cases where extreme suppressive measures make it necessary. Many insect-ridden trees have recovered fully.

(*e*) Cut no thrifty tree that is not interfering with the growth of a more valuable one unless it can be replaced by something better.

(*f*) Confine hardwood growth as far as possible to the best available soils.

(*g*) Encourage the growth and development of conifers, particularly white pine, on all sites not well adapted to hardwood growth.

(*h*) Keep woodland so completely stocked with trees that undergrowth providing gipsy-moth food will be shaded out.

(3) That the establishment of public forests be given every encouragement.

PART II: MANAGEMENT OF TYPICAL WOODLOTS INFESTED WITH THE GIPSY MOTH IN THE WHITE-PINE REGION.

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The preceding pages have been devoted to the general subject of the gipsy moth in woods. In those which follow an attempt will be made to coordinate the results of the food-plant experiments with known principles of forest management and with economic conditions in the infested region, to see how far we may reasonably expect to rely upon forest management to control the moth.

SUSCEPTIBILITY TO GIPSY-MOTH ATTACK AS A BASIS OF MANAGEMENT.

TYPICAL STANDS COMPARED.

The composition of some of the statnds used in the management experiments was shown in Part I (p. 6). By taking these same stands and grouping the species according to their susceptibility to attack by the gipsy moth, as determined by Mosher[1] we get the following results:

Composition of stands by percentage of susceptible trees present.

Classes of trees based on acceptability as food for gipsy-moth caterpillars.	Dover, Mass.	Exeter, N. H.	Wareham, Mass.	North Berwick, Me.	Amesbury, Mass.	Medfield, Mass.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
I. Favored food in all larval stages	94	88	83	50	45	38
II. Favored food after earlier stages	3	4	16	4	36	61
III. Not particularly favored food	2	8	1	45	12	1
IV. Unfavored food	1	....	....	1	7	....
Whole stand	100	100	100	100	100	100
Number per acre alive	510	291	306	407	321	426
Average diameter breast high in inches	4.9	6.1	7.0	6.5	4.9	6.6
Number of species	8	15	9	14	19	6

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[1] Food Plants of the Gipsy Moth in America, F. H. Mosher, Bulletin 250, U .S. Dept. of Agriculture, 1915.

These stands were carefully selected after a thorough search of the infested region to find stands having varying proportions of different species, and they are typical of the region.

It will be noticed that in the first four the Class I trees (favored food of the gipsy-moth caterpillar) from 50 to 94 per cent of the whole stand. It is obvious that in such cases any plan which prescribes the removal of all Class I trees involves a radical change in composition and can not be efficacious unless the sprouts which follow cutting are also removed.

This classification of trees according to their susceptibility to attack by the gipsy-moth caterpillar, though based upon careful experiments in the laboratory and extended observations in the field, is not absolute. In some cases it may have a direct bearing upon forest management in the region infested with the gipsy moth, but it is not yet conclusive as to moth control, for there is a wide range, for example, between the susceptibility of white oak and of beech, which are both Class I trees. It is, therefore, subject to revision, if later experiments or field observations should require it.

OTHER FACTORS IN MANAGEMENT FOR MOTH CONTROL.

A sound plan for moth control by forest management must be based not only upon the susceptibility of the trees to attack by the caterpillars and upon their silvicultural requirements as individuals and as component parts of the stands in which they occur, but also upon the degree of infestation. In the work of the Bureau the degree of infestation by the gipsy moth is determined by counting the number of egg clusters, each containing from 300 to 500 eggs and laid by a single female.

The number of egg clusters per acre at any given date, while by no means satisfactory, is the best standard as yet available by which to compare the degree of infestation in different stands, or in the same stand in different years. It is, of course, a better index of the defoliation to be expected the next year than of that which occurred the year the eggs were laid, and as such becomes a factor in management for moth control. It should be remembered, however, that when very high figures are reached relief may reasonably be expected from outbreaks of the wilt disease,[1] migration of the caterpillars, attacks by parasites and other insect enemies, starvation, or other natural causes.

SOME CONTROLLING FACTORS IN MANAGEMENT.

Since Mosher has concluded that "tray work and field observations show that the white oak is probably the most favored food plant of the gipsy moth," the percentage of white oaks has been selected as a basis of comparison for the six stands now under consideration.

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[1] Glaser, R. W., and Chapman, J. W. The wilt disease of gipsy moth caterpillars. *In* Jour. Econ. Ent., v. 5, p. 479–488, 1913. See Bibliography, p. 487–488.

The percentage of white oaks present gives a natural and definite basis of comparison which has a direct bearing upon both management and moth control.

With the exception of tamarack, there are no conifers among Class I trees (favored food of the caterpillar). As there is no tamarack on any of the lots now under consideration, the retention of conifers is an important factor in moth control in these stands. In any stand the leading species—that occurring in the greatest number—requires careful consideration both as a food plant and as a forest tree if success is to be expected. The presence in large numbers of young growth of species desirable from both viewpoints is also important. This brief statement by no means includes all factors which must be considered, but the suggestions given below are based upon them and upon markets as controlling factors in management. For convenience of reference four of the important factors are summarized in the form of a table which follows:

Some controlling factors in management.

Stand at—	White oak.	Conifers.	Leading species.		Number of gipsy-moth egg clusters per acre in 1913.
	Per cent.	*Per cent.*		*Per cent.*	
Dover, Mass.	38	3	Red oak	45	15,000
Exeter, N. H.	30	4	do	31	949
Wareham, Mass.	21	16	Scarlet oak	54	12
Medfield, Mass.	10	9	Chestnut	52	4,374
Amesbury, Mass.	5	41	White pine	28	550
North Berwick, Me.	....	4	Beech	45	1

TREES WHICH CONTROL.

From the list of 150 food plants of the gipsy moth, published in Bulletin 250, there were selected and considered in Part I all native or naturalized trees which might be found in woods in the infested region. Seventy-five species are included, and the list is given on pages 8–10.

When sufficiently numerous in a stand these would be leading species, as that term has been defined above, and by that fact alone they might become controlling factors in management, but many trees[1] in the list occur so infrequently or are so small that their presence or absence in a stand would have no controlling effect upon the form of management to be practiced.

Of the whole 75 species only 18 have silvical characteristics which, apart from any considerations of commercial value or of moth control, make it impossible to disregard them if success is to be expected in managing a stand in which they are present.

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[1] See Appendix, p. 51.

The possession of these charactertistics puts these 18 trees in a separate class from the others, and the clear recognition of what the characteristics are will greatly simplify our problem and seems to justify the designation of these species as "controlling trees." Unless exactly understood, this term may lead to confusion. Perhaps "potentially controlling trees" would more accurately describe what is meant.

Their mere presence in a stand does not necessarily make them controlling. If one or more of these species is present in such numbers as to be the leading species, no confusion can arise, for their mere numbers make them a controlling factor, and their silvical characteristics reenforce and strengthen their power of control. When less numerous, the question whether or not a particular species is one of the controlling factors depends upon a careful consideration of how many trees there are of each species and of the effect likely to be produced upon the stand by the other controlling factors in that stand.

The chief silvical characteristics which under certain conditions may make these species controlling factors in management are:

(1) Adaptability to certain sites;
(2) Tolerance of shade;
(3) Power of abundant reproduction by seed;
(4) Power of abundant reproduction by sprouts or by root suckers;
(5) Rapid growth.

Of the species possessing one or more of these silvical characteristics, there are listed as controlling trees only those which are actually found, in some stands in the white-pine region, in sufficient numbers to become a controlling factor in those stands. What constitutes sufficient numbers is, of course, a matter of opinion upon which individual foresters may differ. That of the present writer will appear later in the suggestions for management of each of the stands now under consideration.

The list given below includes 18 species falling within the limitations above described. They may fairly be called controlling trees of the white-pine region. In a table which follows the list these species are shown again, grouped under the silvical characteristics which determined their inclusion in the list. This is followed by a brief statement for each species of the conditions under which the potentially controlling trees may become actual controlling factors in management in individual stands in the white-pine region.

In the suggestions for management which follow later all other species are disregarded or are given only the most general consideration.

CONTROLLING TREES OF THE WHITE-PINE REGION AND THEIR CHIEF SILVICAL CHARACTERISTICS.

CLASS I: SPECIES THAT ARE FAVORED FOOD OF THE GIPSY-MOTH LARVÆ IN ALL THEIR STAGES.

Aspen (*Populus tremuloides* Michx.).
Aspen, Large-tooth (*Populus grandidentata* Michx.).
Beech (*Fagus atropunicea* [Marsh.] Sudw.).
Birch, Gray (*Betula populifolia* Marsh.).
Oak, Scrub (*Quercus pumila* [Marsh.] Sudw.).
Oak, Black (*Quercus velutina* Lam.).
Oak, Red (*Quercus rubra* Linn.).
Oak, Scarlet (*Quercus coccinea* Muench.).
Oak, White (*Quercus alba* Linn.).

CLASS II: SPECIES THAT ARE FAVORED FOOD OF THE GIPSY-MOTH LARVÆ AFTER THE EARLIER LARVAL STAGES.

Chestnut (*Castanea dentata* [Marsh.] Borkh.).
Hemlock (*Tsuga canadensis* [Linn.] Carr.).
Pine, Pitch (*Pinus rigida* Mill.).
Pine, White (*Pinus strobus* Linn.).

CLASS III: SPECIES THAT ARE NOT PARTICULARLY FAVORED, BUT UPON WHICH A SMALL PROPORTION OF THE GIPSY-MOTH LARVÆ MAY DEVELOP.

Maple, Red (*Acer rubrum* Linn.).
Maple, Sugar (*Acer saccharum* Marsh.).

CLASS IV: SPECIES THAT ARE UNFAVORED FOOD OF THE GIPSY-MOTH LARVÆ.

Ash, White (*Fraxinus americana* Linn.).
Cedar, Red (*Juniperus virginiana* Linn.).
Cedar, White (*Chamaecyparis thyoides* [Linn.] B. S. P.).

Chief silvical characteristics of controlling trees of the white-pine region.

Gipsy-moth caterpillar food class.	1. Adaptability to certain sites.	2. Tolerance of shade.	Power of abundant reproduction—		5. Rapid growth.
			3. By seed.	4. By sprouts or by root suckers.	
I	Aspen		Aspen	Aspen	Aspen.
	Aspen, Large tooth		Aspen, Large tooth	Aspen, Large tooth	Aspen, Large tooth.
		Beech		Beech	
	Birch, Gray		Birch, Gray	Birch, Gray	Birch, Gray.
	Oak, Scrub			Oak, Scrub	
				Oak, Black	
				Oak, Red	
				Oak, Scarlet	
				Oak, White	
II	Chestnut			Chestnut	Chestnut.
	Hemlock	Hemlock			
	Pine, Pitch		Pine, Pitch		
	Pine, White	Pine, White.	Pine, White		Pine, White.
III	Maple, Red			Maple, Red	
	Maple, Sugar	Maple, Sugar			
IV	Ash, White		Ash, White	Ash, White	Ash, White.
	Cedar, Red				
	Cedar, White				

CONDITIONS UNDER WHICH POTENTIALLY CONTROLLING TREES OF THE WHITE-PINE REGION MAY BECOME ACTIVE CONTROLLING FACTORS IN MANAGEMENT.

THE ASPENS.[1]

The aspen and large-tooth aspen, if few in number in a stand, may be disregarded. They will not control the form of management; that is, they may be cut or left according to the owner's preference. If very numerous or if in pure stands they can not be disregarded, and they become controlling factors because of their rapid growth and power of abundant reproduction by root suckers.

Even if not numerous in the stand then under consideration, these species may be controlling factors in management in that stand if there are numerous seed trees near by, or if the stand contains relatively large areas of bare mineral soil or has recently been burned over. This is because of their power of abundant reproduction by seed and their ability to germinate on such sites.

BEECH.

The power to survive under dense shade and to reproduce vigorously from root suckers makes the beech a controlling factor in management of stands where it is found in sufficient numbers. It sprouts from the stump, but these sprouts seldom amount to anything. In the southern part of the white-pine region beech reproduction is chiefly by root suckers. In the northern part it can be more easily eliminated from stands if this is desired, because there it reproduces chiefly from seed.

GRAY BIRCH.

Many stands of gray birch, covering in the aggregate large areas, are found throughout the white-pine region. They are characteristic of old pastures, and the rapid growth and the power of abundant reproduction of this species, both by seeds and by sprouts, make it an exceedingly difficult and expensive undertaking to eliminate it or even to alter materially the composition of stands in which it is numerous. Under such conditions it becomes a controlling factor in management and can not be disregarded, if success is expected.

SCRUB OAK.

This species (*Quercus pumila* [Marsh.] Sudw.) occupies large areas of so-called waste land, especially in southeastern Massachusetts. The sites on which it occurs are often too poor for agricultural crops but excellent for tree growth, which in most cases originally occupied them. The seeding and sprouting capacity of the species and its ability to grow in soil too poor for other oaks have enabled it to maintain itself and to increase the area occupied in spite of cutting and fires which have reduced the proportion of the pine originally present. These characteristics make the species, although seldom fit even for saleable firewood, a controlling factor in management when it is found in sufficient numbers.

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[1] For further details see Forest Service Bulletin 93, The Aspens, Their Growth and Management, by W. S. Weigle and E. H. Frothingham.

BLACK, RED, SCARLET, AND WHITE OAKS.

These oaks should be confined to soils best adapted to their requirements. Such soils are often suitable for agricultural crops. Sites too rough for agriculture are often excellent for hardwoods other than oak or for white pine. To one knowing nothing about it, it sounds very simple to cut the oaks and plant pine, but the power of abundant reproduction by sprouts, common to these species, makes such a conversion a difficult and expensive proceeding, and owing to this their presence in a stand in sufficient numbers makes them controlling factors in management.

CHESTNUT.

Chestnut has an intolerance of shade which prevents the seedlings from coming up in any dense shade, even that of sprouts of the same species. The supply of seed is usually scanty, owing to the general practice of gathering the nuts. These facts, and its power of abundant reproduction by sprouts and their very rapid growth, all unite to make sprout growth the usual form in which the tree is found in this region.

It does not need a rich soil, but to make good growth requires depth and a soil whose physical structure insures good drainage. It will succeed on soils too dry for beech or maple. There are large areas of glacial drift throughout the white-pine region well adapted to chestnut. It is never found in stands 100 per cent pure, but mixed hardwood stands with 60 to 80 per cent of chestnut are not uncommon. When so numerous on suitable sites its sprouting capacity and rapid growth make this species a controlling factor in management.[1]

HEMLOCK.

That portion of New England now infested with the gipsy moth is not especially adapted to hemlock, which reaches its largest size in the coves of the mountains of West Virginia, North Carolina, and Tennessee. In the white-pine region pure hemlock stands are rare, and the proportion of the area now bearing any hemlock is small.

It is confined, as a rule, to moist ravines and cool slopes, where it should be permanently retained, for its adaptability to such sites makes it there a controlling factor. For the protection of watersheds which should never be denuded, hemlock is especially well suited. Where the retention of hemlock is desired, stands should never be clear cut but should be handled on the selection system, described later. (See p. 44.)

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[1] The susceptibility of chestnut to the chestnut bark disease is another factor that must be considered in this connection. See comment on page 40.

Its tolerance of dense shade and its ability to grow vigorously after a long period of suppression may make hemlock a controlling factor when found as an understory in any stand with an overstory of other species. If fires are excluded, and the trees composing the overstory are not removed too suddenly, hemlock will eventually occupy the site. If this too sudden removal is intentionally prevented by careful management, the understory of hemlock will materially increase the yield from the area occupied and will protect and enrich the soil, but its growth is so extremely slow that, where the object of management is timber production, hemlock should never be grown as the principal crop on level land with soil suitable for agriculture, or on sites suitable for tree species of greater value and of more rapid growth.

PITCH PINE.

Pitch pine is very intolerant of shade and soon dies if overtopped. It is fire resistant; even the seedlings will survive a fire which would kill any other New England species. It bears large crops of seed every year and begins to form cones at an early age. It withstands drought well, and its seedlings require no shade. It does best on good soil, but can not there compete with less intolerant or with more rapidly growing species. Scattered specimens may be found on such sites, but there it is not a controlling tree. Pure stands are found only on sites either too poor or too exposed for other species or so frequently fire swept that other species have been eliminated. When found on such poor sites pitch pine is absolutely controlling, for no other native species will grow there. When mature, the stand may be clear cut and the site planted to pitch pine, or seed trees may be left about 10 per acre, or the area may be seeded artificially.[1] On the better sites pitch pine will be a controlling tree only if, and as long as, the fire hazard remains. When this is removed, more valuable species may return very gradually if seed trees are within reach, or they may be introduced by planting. It is believed that the presence of scrub oak on fire-swept soils is a safe indication that the site occupied is not of the poorest class.

Within the white-pine region pure stands of pitch pine are now found chiefly in the following places: In Maine, south and west of the

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[1] 1912 Conn. State Foresters Report, p. 472, Plot No. 3, 1.3 acres of "natural sand plain" at Windsor. Seed sown on cultivated strips, 1½ feet broad and 4 feet apart. Seed slightly covered by brushing the surface. Two pounds of seed per acre on one-half of the area; one pound per acre on the other half. Conclusion after 10 years: "A stand of this species may be successfully established in this manner. Two pounds of seed per acre gives too dense a stand; 1½ pounds would be sufficient."

Androscoggin and along the Saco River;[1] in New Hampshire on the Saco watershed, especially around Silver Lake in Madison and near Ossipee Lake;[2] in Massachusetts on Cape Cod. It is also found in Connecticut, outside the white-pine region, on the sand plains of the lower Connecticut Valley.[3]

WHITE PINE.

White pine is adaptable to many sites, dry or moist, poor or good. Its seedlings do not often survive if they germinate either in the open or under a heavy shade. They do best under a light shade, such as that of gray birch or aspen, and will persist there until the older hardwood trees die or are passed by the pine. These qualities and its very rapid growth make white pine a controlling tree when its seedlings occupy the ground beneath gray birch or aspen, or when older pines are mixed with other hardwoods of less or of equal height. Unlike the pitch pine, abundant seed crops of white pine are produced only at irregular intervals of four to seven years. This irregularity and the generally unsuccessful attempts to secure natural reproduction make white-pine seed trees on or near the lot of much less practical importance than would be supposed from reading existing literature on the subject, though if such seed trees are present, and the stand is cut in a white-pine seed year, a new stand of white pine may occasionally be secured by natural seeding.[4]

RED MAPLE.

Red maple is found throughout the white-pine region, often pure in swamps or scattered there, or even on dry uplands. Reproduction is good, for this species produces abundant seed crops every year which ripen in the spring, and when cut, the stumps sprout vigorously. In the wettest swamps it grows more rapidly than any other hardwood species and when found pure on such sites is a controlling tree. Such stands should be managed to produce cordwood, by clear cutting, with sprout reproduction, on a rotation of 30 to 35 years.

SUGAR MAPLE.

In eastern Canada and in the northern hardwoods region of New England sugar maple is an important species. In the white-pine region only scattered individuals are found except in southern Maine and southern New Hampshire. There the tree is more common in the woods, and some "sugar orchards" are found. Its seed ripens in October. Some is produced nearly every year, but full crops are borne only at intervals of three to five years. Next to beech, sugar maple is probably the most tolerant of American hardwoods. In youth shade is an advantage, but at maturity full light is not detrimental. It grows slowly and is a strong, vigorous, aggressive species able to hold its own with any trees on soil suited to it, but it is not a "poor-land" tree. It does not grow in swamps. It prefers a fresh, well-drained soil, and in New England finds ideal conditions at moderately high elevations on cool northerly slopes. Its adaptability to such sites and to soils containing lime, together with its tolerance of dense shade, make it a controlling tree when found there in sufficient numbers, either in the main stand or in the young growth beneath it.

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[1] Maine Forest Commissioners 1906 Report, page 9.

[2] N. H. Forestry Commission Report for 1903–4, pages 61, 68.

[3] Hawley & Hawes, Op. cit., p. 42.

[4] The susceptibility of white pine to the white-pine blister rust is another factor that must be considered in this connection. See comment on page 40.

WHITE ASH.

White ash resembles hemlock in the ability of its seedlings to start in dense shade and to respond well when released, but the length of time it can stand suppression is much less than that of hemlock. Like other species, white ash is more intolerant on poor than on good sites. After the pole stage it can endure only a moderate amount of shade. It is found, except on poor, dry sites, throughout New England, but is of greater importance in the northern hardwoods and sprout hardwoods regions which adjoin the white-pine region at the north and south. White ash occurs usually as scattered individuals in second-growth mixed hardwood stands on the richest soils now forested. It is not a swamp tree, but requires deep, fertile, and well-drained soils, with abundant moisture available near the surface. Gentle north or east slopes are especially favorable sites.

It sprouts vigorously when cut, seeds freely about every other year, with exceptionally heavy crops at intervals of three to five years. It starts well in openings in broken hardwood stands and also on pine needles under pure second-growth white-pine stands, if not too dense. It also seeds in well after a fire, if the site is sufficiently moist and seed-bearing trees are near. It grows more rapidly than the other hardwoods with which it is usually found and occasionally forms 25 per cent or more of mixed second-growth hardwood stands along streams or lakes on rich, moist, well-drained soil. Under these circumstances its adaptability to the site, its rapid growth, and its power of abundant reproduction by seed and by sprous make it a controlling tree. Such stands may be clear cut if they offer an open seed bed, or they may be handled on the shelterwood system if the stands are dense.

RED CEDAR.

Red cedar is widely distributed in the eastern United States, but only in the Southeast, on good soil, is it now found in the quality and sizes which give it its greatest value. In New England it ranges from Augusta, Me., and from southern New Hampshire through Massachusetts and Rhode Island into Connecticut. It is charactertistic of old fields and pastures, the stands varying from a few scattered trees to dense pure stands, and it is also found in mixture with gray birch and with other trees.

Within the white-pine region thousands of acres in the aggregate are covered by this typical growth, which can not be cut profitably until the cedar is large enough for posts and the birch for cordwood. On such sites, when found in sufficient numbers, and on rock covered with not more than 6 inches of soil, where no other tree can grow, red cedar is a controlling tree.

When cut from such rocky sites it should be replaced by seeding or by planting 4-year-old red-cedar stock, three times transplanted in the nursery.

On old fields and pastures thinning is not recommended, even in dense stands, as the increased growth is so slow that thinning will not pay.

The general object of management should be to replace the cedar with more rapidly growing species. When material is large enough to sell, stands should be clear cut and planted. In the meantime open stands of cedar not ready for clear cutting should be filled by planting white or red pine, and mixed stands handled as suggested for the stand at Amesbury, Mass., described later. That stand is characteristic old-field growth, with a small percentage of red cedar.

WHITE CEDAR.

This species, *Chamaecyparis thyoidse* (Linn. B.S.P.), must not be confused with the other of the same common name, *Thuja occidentalis* Linn., also found in New England and often called arborvitæ. Arborvitæ is rarely seen south of Boston, and Chamæcyparis perhaps as rarely north of that city. Although not unknown in southern Maine and southern New Hampshire, it is not found in commercial quantities in the white-pine region except in certain swamps within 20 miles of the coast in Massachusetts, Rhode Island, and Connecticut.

It is found pure and also mixed with red maple. Many swamps in which it formerly grew have been cleared and converted into cranberry bogs, and others not suitable for cranberries will probably eventually be drained and used for other agricultural crops.

Until this is done no attempt should be made to eliminate white cedar from such sites for, in spite of its very slow growth, it is there, on account of its adaptability to the site, a controlling tree. Its cones mature at the end of the first season and persist through the winter. White cedar readily starts from seed and should be managed by clear cutting in small groups or in strips not wide enough to offer much danger from windfall.

TYPICAL STANDS.

Having now considered the factors involved in any attempt to control the gipsy moth by forest management, let us see how they apply in typical stands.

The stands previously mentioned will be discussed in the order given on page 19, and readers should remember that any general statement or suggestion referring to a class is intended to apply to that class as represented in the stand then under consideration and may not be applicable to the species composing the class when found in other stands, especially if they occur there in different proportions.

STAND AT DOVER, MASSACHUSETTS.

THE MANAGEMENT OF A TYPICAL MIXED OAK STAND WITH ABOUT FOUR-TENTHS WHITE OAK.

The woodlot contained eight species on 1 acre, but since red, white, and black oak together constituted 94 per cent of the whole, it may be considered from the standpoint of management as a mixed oak stand. It is on good soil, a light, brown, sandy loam, not as deep as that of the Exeter plot, but moist and well drained. It is underlain by gray granite ledges which outcrop in a few places but occupy less than 1 per cent of the area. The surface is free from loose stones, but there is one large granite boulder. The trees averaged 4.9 inches in diameter breast high and, excepting the white pines, were about 30 years old.

The infestation by the gipsy moth was first found near this lot in 1905, and in 1913 the egg clusters present on this area were estimated at 15,000 per acre, and defoliation was heavy.

If the stand were not infested it could be handled as a sprout forest[1] on a rotation of 70 to 80 years, with several thinnings. The thinnings should yield enough cordwood to pay for them, and the final product, cut 40 or 50 years from now, would be good oak timber.

It has been the practice in eastern Massachusetts, in town, State, and Federal work, and by some owners of heavily infested stands of this character, to remove all dead trees and as much undergrowth as possible and make a heavy thinning. This has been done to simplify *spraying*, which is effected by a high-power sprayer, resembling in size and general appearance the watering carts used in city streets. Spraying costs from $8 to $15 an acre, which must be spent each year while the infestation continues heavy and is efficacious in stopping defoliation at the stage reached when the spraying is done. It generally reduces the number of caterpillars but cannot prevent all damage by them, for its effect is dependent upon the leaves being eaten by the caterpillars.

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[1] Simple coppice system.

Management for moth control may be attempted by making one cutting or by successive cuttings.

One cutting.—The expense of spraying may be entirely avoided in stands of this character by clear cutting, leaving conifers if desired, and planting red or white pine. If this is done it must be followed by several *cleanings* (removing the hardwood sprouts), or the caterpillars in their early larval stages may feed on the hardwood foliage and in their later stages attack the pine.

It should be remembered, however, that the gipsy moth increases in numbers less rapidly on young hardwood sprouts than on larger trees of the same species, whether these are of sprout or of seedling origin. When the object of management is moth control, this less rapid increase, of course, affects the number of cleanings which are needed in young sprout hardwood stands after cutting.

After various experiments the conclusion has been reached that cleanings in the first, third, and fifth years following a clear cutting in hardwoods will be ample to insure protection to small planted pines and that in many cases the interval between cleanings may safely be increased to three years, and the first one postponed until the second year after the original cutting.

From purely silvicultural considerations the presence of hardwood sprouts on the ground during the first summer after clear cutting is likely to be beneficial to small planted pines by providing some shade, and a cleaning in the second and another in the fourth or fifth year following clear cutting would prevent the small pines from being killed out or so suppressed that their growth would be seriously checked.

From considerations both of silviculture and of moth protection an owner planning to cut clear a mixed oak stand and to plant pine should be prepared to make two and perhaps three cleanings, and should realize that even more may be necessary.

The product of clear cutting on this lot would be about 20 cords of good cordwood per acre, which is practically unsalable in this locality because of the great amount of cutting now being done. If sold, the most that can reasonably be expected for it is $2.50 per cord on the lot. The cost of cutting should not exceed $1.25 per cord. The planting, including stock, will cost from $12 to $15 per acre.

The cost of a cleaning made the first year after cutting will be less than one made the second year, because of the great difference in the size of the sprouts. If made the first year it will require seven or eight hours' labor of one man. If made the second or third year, it may well take 10 or 11 hours. Great care must be used to avoid damage to the small planted pines.

Removing sprouts by mowing is especially dangerous to young growth, wild or planted, which it is desired to retain, and any form of cutting is less effective and must be repeated more often than breaking or pulling the sprouts from the stump. Pounding them off with the poll (back) of an ax is especially desirable, and the first year after trees are cut sprouts may be removed by trampling around the stump. This method is especially successful with oak sprouts and is not very hard on the feet if heavy shoes are worn.

The time of year when trees are cut has an important bearing on the number and vigor of sprouts which follow, and the same is true of removing sprouts. The best time undoubtedly varies with the species and locality, even in an area as small as New England, but no precise information on this subject is available. Speaking generally, it may be said that trees cut in the summer have less vigorous sprouts than those cut in May or June. The same conditions apply to sprouts. If these are removed in July or August those which follow are smaller and more tender than those which follow sprouts removed earlier in the season and are likely to be killed or damaged by frost. The result of clear cutting, planting, and cleaning in this stand, if fires are excluded, would be a pure stand of young pine on good soil, which should grow rapidly, yield a high return, and be secure against gipsy-moth attack.

The owner of this stand, like many others in the infested region, was unwilling to make a clear cutting but very anxious to control the gipsy moth. In such cases the plan offering the best chance of eventually controlling the gipsy moth is to begin the gradual conversion of the stand from hardwoods to pine by successive cuttings.

Successive cuttings.—The first cutting, to be made at once, should remove all dead, dying, defective, or suppressed trees. All Class I trees (most favored food of the caterpillar) should be cut as heavily as is possible without exposing the ground too much. Many trees of this class must be left, but they should be, as far as possible, thrifty trees of seedling origin, and a particular effort should be made to reduce the number of white oaks.

The Class II trees (favored food after the earlier larval stages) will be favored in this cutting. On this lot they were white pines large enough for seed trees and so especially desirable.

The Class III trees (not particularly favored food) will also be favored in the first cutting. On this lot these were only a few red maple and pignut hickory.

The Class IV trees (unfavored food) will not be cut, even if defective or suppressed. On this lot they were white ash.

In a stand as dense as this (500 trees per acre) about 60 per cent of the total number present should be removed. The result upon the actual stand now under consideration, of following either of the two plans of cutting proposed, appears clearly in the following table:

Stand and cutting table, Dover, Mass. Mixed oak stand, four-tenths white oak.

Trees which control if in sufficient numbers.	Original stand.			Number per acre left under two plans proposed.		
	Trees which control on this lot.	Other species present.	Number per acre.	1. Radical conversion—one cutting (now).	2. Gradual conversion—successive cuttings. First (now).	2. Gradual conversion—successive cuttings. Second (in 5 to 10 years).
Class I:						
Red oak	Red oak		229		130	
Black oak	Black oak		59		36	
White oak	White oak		193		28	
Gray birch		Gray birch	1			
Class II:						
White pine		White pine	17	17	17	17
Class III:						
Red maple		Red maple	5		2	2
		Hickory	3		2	2
Class IV:						
White ash		White ash	3		3	3
			510	17	220	24

The lot should be planted at once with some moth-resistant species. Red or white pine, or a mixture of both, may be used, 1,000 to the acre, with entire confidence.

The site as a whole is too dry for white ash, but a few, 25 or 50, could be planted at the lowest part of the lot with benefit to its eventual moth-resistant character.

Cleanings will be necessary for at least five years, as in the case of clear cutting. (See p. 29.)

The second cutting should be made just as soon as the trees planted are established and have gained a decisive lead over the sprouts from stumps of trees cut. This would be not less than five years after the first cutting. If it were delayed until 10 years after, the planted trees would probably be secure against being overtopped by sprouts from the second cutting. If cut after five years, a cleaning in the second and another in the fourth year would probably be necessary. The second cutting should remove all remaining Class I trees of the original stand, leaving the Class III and Class IV trees. The white pines of the original stand will be large enough to cut profitably at this time, but might better be left as standards to supply some extra-large material in the final cutting of the planted stand.

The product of the first cutting will be cordwood, about 8 or 9 cords per acre, worth not more than $2.50 per cord on the lot. In addition there will be 3 or 4 cords of poor cordwood, probably worth about what it cost to cut or a little less. The product of the second cutting will depend upon when the cutting is made. There will be only cordwood unless the cutting is delayed for 40 to 50 years, or until the stand is 70 to 80 years old, in which case material of larger dimensions can be obtained.

After the second cutting some additional planting will probably be necessary to replace trees of the first planting which have died or have been destroyed in the second cutting. The number required should not exceed 300 per acre.

The cost of the first cutting will be about $1.50 per cord and of the second about $2 per cord.

The first planting, including stock, will cost about $15 per acre, and the second planting $4 or $5 per acre. The higher cost, as compared with planting after clear cutting, is due to the need of going over the ground twice and to the care necessary to avoid damage to young growth when the two plantings are made.

A cleaning the first year after the first cutting will require four or five hours' labor per acre of a careful man; and the cost will depend, of course, upon whether the owner does the work himself, has such a man available, or must employ one especially for the work.

Later cleanings after the first cutting and the two biennial cleanings after the second cutting are each likely to require somewhat more time, as greater care will be needed to avoid doing damage to planted stock, but six to eight hours per acre should suffice.

The result will be, if fires are excluded, a moth-resistant stand of a composition dependent upon the species selected for planting.

The cost of either plan would be heavy, and for most owners, especially if applied to large areas, it would be prohibitive. But where the infestation is severe either plan of management offers improved conditions at less expense than spraying for five years at $15 per acre.

With a good cordwood market the first plan, clear cutting, should yield a slight margin of profit over all costs. The second plan involves a considerable investment without any net returns up to the time the conversion from a susceptible to a resistant stand is completed.

Where the moth is present in large numbers this should be compared with the cost of spraying and creosoting, and the net cost of converting the stand regarded as the price the owner has paid for the satisfaction of not denuding his land, for relief from annual expenses, the results of which are only palliative, and for future insurance against damage by the gipsy moth.

The possibility of control by management, without planting, is the object of experiments now in progress.[1] Pending their conclusion, it is believed that sufficient information has been given in the foregoing to guide owners of stands of this character who wish to do something at once.

Of the two plans outlined, the first, clear cutting and immediate planting of the whole area, is preferable from considerations of forest management, of moth control, and of minimum expense. Economic conditions preclude the expectation of its general adoption in the near future, but it is strongly recommended to owners willing to meet the expense.

Others must face the fact that they can not at present expect to secure moth control by forest management.

STAND AT EXETER, NEW HAMPSHIRE.

THE MANAGEMENT OF A TYPICAL MIXED OAK STAND WITH THREE-TENTHS WHITE OAK.

The woodlot of 2.5 acres contained 15 species, but since red, white, and black oak together constituted 87 per cent of the whole, it may be considered from the standpoint of management as a mixed oak stand. It is on good agricultural soil, a dark, brown, sandy loam, deep, moist, and well drained. The trees averaged 6.1 inches in diameter breast high and about 35 years old.

The surrounding region had been infested with the gipsy moth since 1908, the infestation coming apparently from the northeast. In 1913 the count on this lot disclosed 949 egg clusters per acre. There was very severe defoliation, but it was not all due to gipsy-moth caterpillars. They were responsible for part of it, but a very large part was the work of brown-tail and forest tent caterpillars.

If the stand were not infested, it could be handled like that at Dover, as a sprout forest.

If the owner wishes to attempt to control the gipsy moth by forest management, the two methods suggested for Dover will be applicable, with certain modifications.

One cutting.—If cut clear and planted, the products will be less, because, though the trees averaged a little larger, there were only three-fifths as many—300 per acre. The product will probably be about 20 cords of good cordwood per acre, worth, as this lot is situated, about $3 per cord on the lot.

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[1] See also, Results of Experiments in Controlling the Gipsy Moth by Removing Its Favorite Food Plants. By A. F. Burgess and D. M. Rogers, Journal of Economic Entomology, Vol. VI, pp. 75 to 79 (1913).

Successive cuttings.—If the plan is adopted of making a gradual conversion of the stand from hardwoods to pine, the first cutting may be made on the same general plan as at Dover, but should remove not over 40 per cent of the total number of trees present, because this stand is much less dense.

The result upon this stand appears in the following table:

Stand and cutting table, Exeter, N. H. Mixed oak stand, three-tenths white oak.

Trees which control, if in sufficient numbers.	Original stand.			Number per acre left under two plans proposed.		
	Trees which control on this lot.	Other species present.	Number per acre.	1. Radical conversion—one cutting (now).	2. Gradual conversion—successive cuttings.	
					First (now).	Second (in 5 to 10 years).
Class I:						
Red oak	Red oak		89		64	
Black oak	Black oak		77		62	
White oak	White oak		84		12	
Gray birch		Gray birch	1			
Large-tooth aspen		Large-tooth aspen	1			
Beech		Beech	2			
		Apple	(1)			
Class II:						
White pine		White pine	11	11	11	11
Pitch pine		Pitch pine	(1)	(1)	(1)	
Class III:						
Red maple		Red maple	20		13	13
		Yellow birch	(1)		(1)	(1)
		Black birch	1		1	1
		Hickory	2		2	2
		Black cherry	(1)		(1)	(1)
		Elm	(1)		(1)	(1)
Class IV:						
None						
			291	11	166	28

[1] Less than one tree per acre.

Planting should at once follow the first cutting. Red or white pine, 1,000 to the acre, may also be used here, but a larger part of the area is suitable for white ash. It is possible that on sites of this character a mixture of 5 per cent of tulip tree or white ash with the pine would be advantageous. White ash may also be planted pure on deep moist soils in areas not exceeding one-half acre in extent.

The time of making the second cutting and the need of a second planting will be determined by the same considerations as at Dover.

The product of the first cutting will be cordwood, 7 or 8 cords per acre, and, unless tops and limbs are burned, 3 or 4 cords of poor cordwood worth less than it cost to cut.

The costs of cutting and of planting should not differ much from those at Dover, and for the same reasons which apply there the first of the two plans proposed is preferable from considerations of forest management, of moth control, and of minimum expense.

STAND AT WAREHAM, MASSACHUSETTS.

THE MANAGEMENT OF A TYPICAL MIXED OAK STAND WITH ABOUT TWO-TENTHS WHITE OAK.

The woodlot contained nine species, but since scarlet, white, and black oak together constituted 83 per cent of the whole, it may be considered from the standpoint of management as a mixed oak stand.

It differed from the mixed oak stands at Dover and Exeter in that it was 60 years old, scarlet oak was present and formed over 50 per cent of the stand, white pine was more numerous, the gipsy-moth infestation was very light, and a dense growth of young white pine was already present on parts of the lot.

The soil is a brown, medium-textured, sandy loam with a sprinkling of fine gravel. The surface 2 or 3 inches is gray. The soil is deep and naturally well drained.

On 5.4 acres, where all trees were measured, those trees over 2.5 inches in diameter averaged only 7 inches in diameter breast high. The stand was even-aged and was cut clear about 60 years ago. Many of the larger trees were stagheaded (dead in the tops).

Although the gipsy moth had been present at least since 1911, the infestation in 1913 was very light, averaging only about 12 egg clusters per acre, and the damage done by the caterpillars was not noticeable. The defoliation due to forest tent and geometrid caterpillars was much more severe.

The owner is a manufacturing corporation which uses the lot as a source of supply for material for repairs to its plant.

This cutting of the larger hardwood trees undoubtedly accounts for the low average diameter of the stand, and the practice of making small openings probably explains the presence and location of the dense growth of small white pine found on the lot.

This land is well suited to growing potatoes, berries, and other garden truck, but if it is to be kept as a woodlot the stand should be converted from hardwoods to pine, wholly apart from considerations due to possible damage by the gipsy moth. This can be accomplished by clear cutting in one operation or in two successive operations.

One cutting.—If the stand is cut clear in one operation, all hardwoods should be removed and especial care used to prevent, as far as possible, damage to the young pine already present, which should be supplemented by planting red or white pine on areas not sufficiently stocked.

Cleanings will be needed, about three in all, made every two years, to release the young pine from the hardwood sprouts which are useful at first in providing shade, but, if not removed, will in a short time kill out much of the pine. If cut clear, the hardwoods would yield about 20 cords per acre, but as this lot is maintained for a special purpose, the product should be as far as possible cut in such sizes as the owner requires and the balance put into cordwood. Owing to the care required to avoid damage to young growth, the cost of cutting will be high, perhaps $40 per acre. The cost of necessary planting (400 trees per acre) will average $6 per acre. The three cleanings will require 8 to 10 hours' labor of one man per acre. The result will be a pure stand of young pine on good soil, which, if fires are excluded, should grow more rapidly and yield a greater quantity of wood of higher value than the stand which it replaced, and which in addition will be secure against gipsy-moth attack.

Successive cuttings.—If the plan is adopted of gradually converting the stand from hardwoods to pine, two cuttings should be made. The first cutting, to be made at once, should remove all dead, dying, defective, and suppressed trees. As the gipsy moth is not present in large numbers, the heavy cutting of Class I trees (most favored food of the caterpillar) is not as important as in stands already considered, but since there are almost no other trees present except pines, the cutting above described amounts in this instance to practically the same thing as recommending the cutting of Class I trees of the species found on this lot. The object should be to cut as heavily as is possible without exposing the ground too much and to release all pines in danger of suppression.

The hardwoods left should be as far as possible thrifty individuals of seedling origin. All pines likely to make good trees should also be left. About 50 or 60 per cent of the total number of trees present should be removed.

The areas insufficiently stocked should be planted at once with some moth-resistant conifer. The soil is not suitable for any of the resistant hardwoods. Red or white pine or a mixture of both may be used, as on the lots previously considered, with entire confidence. Owing to the young growth of white pine already present, an average of 400 plants per acre for the whole lot will be sufficient.

Cleanings, about three in all, will be necessary every two years, as in the case of one cutting. These will meet all silvicultural requirements.

The second cutting should be made just as soon as the trees planted are established and have gained a decisive lead over the sprouts from stumps of trees cut. This would be not less than five years after the first cutting. If it were delayed five years longer the planted trees would probably be secure against being overtopped by sprouts from the second cutting. If cut after the first five years a cleaning in the second and another in the fourth year would probably be necessary.

The second cutting should remove all remaining hardwoods, leaving only conifers. If at that time a market or use exists for a small amount of low-grade white and pitch pine, those in the original stand might be cut to advantage, leaving an even-aged stand of pine, but it would probably be better to leave them as standards to supply some extra-large material in the final cutting of the planted stand.

The result of following either of the two plans of cutting in this stand appears in the following table:

Stand and cutting table, Wareham, Mass. Mixed oak stand, two-tenths white oak.

Trees which control if in sufficient numbers.	Original stand.			Number per acre left under two plans proposed.		
	Trees which control on this lot.	Other species present.	Number per acre.	1. Radical conversion—one cutting (now).	2. Gradual conversion—successive cuttings. First (now).	2. Gradual conversion—successive cuttings. Second (in 5 to 10 years).
Class I:						
Red oak		Red oak	(1)			
Black oak	Black oak		24		12	
Scarlet oak	Scarlet oak		164		65	
White oak	White oak		65		10	
Gray birch		Gray birch	(1)			
Class II:						
White pine	White pine		45	45	43	43
Pitch pine	Pitch pine		5	5	3	3
Class III:						
Red maple		Red maple	2		(1)	
Black gum		Black gum	(1)		(1)	
Class IV:						
None						
			306	50	133	46

[1] Less than 1 tree per acre.

As to the products of cutting, the same limitations apply that were considered under the plan of clear cutting in one operation. They should be, as far as possible, what the owner requires and the balance put into cordwood. If the products of the first cutting were all cordwood, there would be about 12 or 13 cords per acre of good merchantable wood.

It is believed that with the small white pine already present and the planting provided for above, no additional planting would be necessary to replace trees which may die or which may be destroyed in the second cutting.

The cost of the first cutting will be about $20 per acre and of the second cutting about $25 per acre. The planting suggested, including stock, will cost about $6 per acre. The biennial cleanings after the first and second cuttings will each require five or six hours' labor per acre of a careful man. The cost will, of course, depend upon local conditions. The result will be the same as would be obtained by clear cutting in one operation—a stand of young pine on good soil, which, if fires are excluded, should grow rapidly and yield a greater quantity of wood of higher value than the stand which it replaced, and which in addition will be secure against possible damage by the gipsy moth. Of the two plans suggested, the former, removal in one cutting, is preferable, because costs of cutting and of cleaning will be less, damage to planted stock will be eliminated, and less time will be required to accomplish the conversion of the stand.

The possibility of control by successive cuttings is the object of experiments now in progress on this and other lots. Pending their conclusion, the removal in one cutting is recommended to owners of stands of this character who wish to do something at once.

STAND AT MEDFIELD, MASSACHUSETTS.

THE MANAGEMENT OF A TYPICAL MIXED HARDWOOD STAND WITH ONE-TENTH WHITE OAK.

The woodlot contained only six species on 1.3 acres, but the three species of oak and the chestnut together constituted 90 per cent of the whole. Since chestnut, the leading species, formed 52 per cent of the stand and is a controlling tree of Class II (not favored food until after the earlier larval stages) and is present in sufficient numbers, it must be the determining factor in management.

The lot slopes gently to the north and northeast and has good soil, a brown sandy loam, deep, moist, and well drained, and free from stones.

The trees averaged 6.6 inches in diameter breast high, about 40 years old, and 426 per acre.

The gipsy-moth infestation was first found in 1909 in similar growth on the adjoining lot to the east, where, in spite of creosoting by the local moth superintendent, 40 per cent of all trees and 80 per cent of the white oaks had died by 1913. On the lot now under consideration the gipsy-moth infestation in 1913 was very severe, but less than 10 per cent of the trees were dead.

The usual form of management recommended by foresters for a stand of this character is the simple coppice system, using a rotation of about 60 years, with several thinnings. This means merely that the stand is to be cut clear at that age and allowed to reproduce by sprouting, after which thinnings are made if possible to do so without loss. To secure gipsy-moth control this should be modified by discriminating against the oaks and eliminating the white oak, which latter may often be done without harmful effects silviculturally in cases like this where white oak forms only 10 per cent of the stand.

Successive cuttings.—As the stand has not been under management and the infestation is heavy, the first cutting, a thinning, should be made at once along the lines indicated above, favoring chestnut and releasing and favoring white pine. Fifty per cent of the total number of trees may be removed without unduly exposing the ground and with real benefit from a general silvicultural standpoint. The result of the thinning described appears in the following table.

Stand and cutting table, Medfield, Mass. Mixed hardwood stand, one-tenth white oak.

Trees which control if in sufficient numbers.	Original stand.			Number per acre left under plan proposed.	
				Gradual conversion—successive cuttings.	
	Trees which control on this lot.	Other species present.	Number per acre.	First (now).	Second (in 20 years).
Class I:					
Red oak	Red oak		91	29	
Black oak	Black oak		29	[1] 26	
White oak	White oak		43		
Class II:					
White pine	White pine		38	32	
Chestnut	Chestnut		219	105	
Class III:					
Red maple		Red maple	6	1	
Class IV:					
None					
			426	193	(2)

[1] In the cutting actually made on this lot, black oak was favored as an experiment, so the table does not in this respect conform to the practice suggested in the text.

(2) See p. 39, last paragraph.

Planting will not be necessary, but cleanings for at least five years (see p. 29), removing all sprouts of Class I trees, will be of great assistance in reducing the amount of food available for first-stage gipsy-moth larvæ and in maintaining the altered composition of the stand. It should be stated frankly in this connection that the entomologists consider the removal of all oaks and other Class I trees as the safest method to follow in controlling the gipsy moth by limiting its food plants. The foresters, however, who are working on the problem consider this most undesirable from the standpoint of management. Both agree that the help to be expected throughout the infested region from parasites and other enemies and periodical outbreaks of the wilt disease, combined with other measures of control, may eventually cause the gradual subsidence of the gipsy moth to a normal place among other injurious insects.

Under the plan proposed, the second cutting will not take place for about 20 years (the end of the rotation), at which time the stand will be cut clear.

By leaving the chestnut sprouts following the thinning and the final cutting and removing sprouts of oaks or other Class I trees in the cleanings, the representation of trees of this class in the succeeding stand should be much reduced. By continuing the same process through succeeding rotations all Class I trees may be removed, and the conversion to a moth-resistant stand would be complete in 80 to 140 years.

The products of the first cutting will be chestnut posts, worth 10 to 40 cents each, and cordwood, about 10 cords per acre, worth $4 per cord on the lot. In addition there will be about 3 cords of poor cordwood which is unsalable in the region. Unless the owner can use it himself, it would be cheaper to burn the limbs and tops as the cutting proceeds than to pay for cutting and piling this low-grade cordwood and then let it rot in the woods. The products of the second cutting will be chestnut of sizes suitable for poles, piles, lumber, ties, and posts, a few oak ties and some good cordwood.

The cost of the first cutting will be about $40 an acre, which should be slightly less than the amount realized from the sale of the products. The cost of the second cutting will, of course, depend upon conditions at that time, about 20 years hence, but the value of the products to be expected should yield a small profit. It is not likely that the net profit of the first cutting will be sufficient to cover the cost of the cleanings recommended. If these are made the cost should be considered as a premium for insurance against damage by the gipsy moth.

By concentrating our attention upon the gipsy-moth problem we are in danger of forgetting the *chestnut-bark disease* and the *white-pine blister rust*, both also imported from abroad and perhaps even more difficult to control. The chestnut-bark disease is present on the lot now under consideration and generally wherever chestnut is found throughout the region infested by the gipsy moth. On the lot now in question and others like it, where a large percentage of chestnut is present and the control of the gipsy moth is the immediate problem, it is believed to be wiser to use the chestnut as long as it lasts rather than to attempt the expensive experiment of a radical conversion of the whole stand to white pine, with the risk of fire, blister rust, and white-pine weevil. Where chestnut does not occur, as in the stands previously considered, these risks may be necessary. Here they are not.

STAND AT AMESBURY, MASSACHUSETTS.

THE MANAGEMENT OF A TYPICAL STAND OF OLD-FIELD GROWTH OF PINE AND MIXED HARDWOODS WITH ONE-TWENTIETH WHITE OAK.

This lot, used as a pasture until 15 years ago, contained 19 species of trees on 4.2 acres, but 95 per cent of the whole number consisted of the following eight species, in the proportions indicated:

	Per cent.		Per cent.
Black oak	16	Red maple	10
White oak	5	Red cedar	5
Gray birch	21	White ash	2
White pine	28		
Pitch pine	8	Eight species	95

The other 11 species, some of them important as timber trees and some from the standpoint of moth resistance, were represented on this lot by too few trees to be important in any plan of management.

The soil is good, a brown sandy loam, deep, moist, and well drained, and the lot is level, except for a small area where water stands late into the spring. It is free from rock or loose stones. When the demand for agricultural land increases sufficiently this lot undoubtedly will again be cleared and cultivated. The trees averaged 4.9 inches in diameter breast high, the same as the Dover stand, but this area was poorly stocked, the stand being very dense in some places and much too open in others, with an average of 321 trees per acre. The infestation by the gipsy moth was very severe in 1913. Several of the white pines were almost bare, with the needles eaten back almost to the sheath. Others were from one-half to three-fourths defoliated.

The present growth is very irregular in size, and if the stand were not infested it is not likely that any owner would consider forest management or would cut the lot before 20 years from now, at which time the hardwoods could be cut clear without loss, although the product would be only cordwood. But if management were begun now the object would be to get rid of the less valuable hardwoods, especially gray birch, and release the pine and more valuable hardwoods by thinning.

Since the stand was infested and Class I trees (most favored food of the caterpillars) formed only 45 per cent of the stand, to cut clear now, as was recommended in the stands previously discussed, would be an unnecessary waste of good species well started. Nor can successive cuttings be recommended in stands of this character. If the danger of soil exposure were serious enough to warrant the expense, the Class I trees might be removed in two successive cuttings as previously described; but when, as in this case, 55 per cent of the stand consists of trees in Classes II, III, and IV, the soil exposure, considering the small area involved, would probably not be a controlling factor.

Gipsy-moth cutting.—Immediate protection against further damage by the gipsy moth can be secured by what may be called a "gipsy-moth cutting."

In its effect upon tree species which are favored food of gipsy-moth caterpillars this resembles a damage cutting in that silvicultural considerations are wholly disregarded as far as these species are concerned. All Class I trees of whatever species are removed, whether of merchantable size or not. At the same time any dead trees are cut, and a light thinning, combined with a liberation cutting, is made in the trees of Classes II, III, and IV. To be effective this must be followed by planting some moth-resistant species suitable to the site and by cleanings until these are established, probably for at least five years. (See p. 29.) Owing to the great number of very small trees, between 1 inch and 2.5 inches in diameter breast high, the cost per cord will be high and the product poor cordwood, about 7 or 8 cords per acre.

For planting on such sites, red or white pine or a mixture of both is recommended, with white ash in the moister situations. Tulip tree should also do well on sites suitable for white ash, but if used it should be considered as an experiment. Under the conditions obtaining on this lot, planting an average of 600 trees per acre should be sufficient, and the cost will be $8 to $10 per acre.

The possibility of control without removing all Class I trees is the object of experiments now being conducted on this and other lots. Pending their conclusion, the above suggestions are made to guide owners who wish to do something at once. Neither clear cutting nor successive cuttings can be recommended in stands of this age and character, and a gipsy-moth cutting can be recommended only for owners who put gipsy-moth control above all other considerations.

The result of the three plans is compared in the table following.

Stand and cutting table, Amesbury, Mass. Old-field growth, one-twentieth white oak.

Trees which control if in sufficient numbers.	Original stand.			Number per acre left under three plans described.			
	Trees which control on this lot.	Other species present.	Number per acre.	1. Radical conversion—one cutting (now).	2. Gradual conversion—successive cuttings. First (now).	2. Gradual conversion—successive cuttings. Second (in 5 to 10 years).	3. Gipsy-moth cutting, see p. 41 (now).
Class I:							
Red oak		Red oak	(1)				
Black oak	Black oak		52		27		
White oak	White oak		16		3		
		Swamp white oak	1				
Gray birch	Gray birch		68		14		
Aspen		Aspen	(1)				
		Apple	3				
Class II:							
White pine	White pine		90	90	90	90	90
Pitch pine	Pitch pine		27	27	6	6	6
Chestnut		Chestnut	(1)		(1)		(1)
Class III:							
Red maple	Red maple		33		22		22
		Black birch	(1)		(1)		(1)
		Hickory	(1)		(1)		(1)
		Wild red cherry	2		(1)		(1)
		Elm	(1)		(1)		(1)
		Hop hornbeam	(1)		(1)		(1)
Class IV:							
Red cedar	Red cedar		15	15	15	15	15
		Butternut	(1)	(1)	(1)		(1)
White ash	White ash		7	7	7	7	7
			321	139	187	118	141

[1] Less than 1 per acre.

STAND AT NORTH BERWICK, MAINE.

MANAGEMENT OF A TYPICAL STAND OF NORTHERN HARDWOODS WITH NO WHITE OAK.

This lot, 4 miles from a prosperous manufacturing town, while within the white-pine region, had a stand characteristic of the northern hardwoods region. It contained 14 species of trees on 3.4 acres, but 98 per cent consisted of the following nine species in the proportions indicated:

	Per cent.
Red oak	2
Paper birch	2
Beech	45
Hemlock	4
Red maple	8
Sugar maple	14
Black birch	4
Yellow birch	3
Hop hornbeam	16
Nine species	98

The soil is a sandy loam, deep and well drained. The surface is very uneven, steep in places and thickly covered with large stones and small boulders.

The trees averaged 6.5 inches in diameter, breast high, but varied greatly in size, the average for the different species ranging from 3 to 15.2 inches, with a few individual trees ranging up to 31 inches in diameter. The gipsy-moth infestation in 1913 was exceedingly light, only one egg cluster per acre, and had not increased much by 1915, although in that year other woodlots in the neighborhood were severely defoliated.

Under present economic conditions the general application of forest management to such lots as this is not to be expected, but the possibility of controlling the gipsy moth by this means is considered here, to complete the comparison between typical stands found within the white-pine region, and for its possible application in special cases. The Class I trees (favored food of the caterpillars) are red oak, paper birch, and beech. Of these beech is the least valuable commercially, unless there happens to be a local demand for the wood, but it is the most desirable from the standpoint of gipsy-moth control. As a result of his observations, Mosher draws this conclusion: "It is evident that the beech must be associated in a mixture with one or more favored species in order that the gipsy moth may reproduce normally."

Anything which adversely affects the normal reproduction of the moth is of value as a control measure. Mosher's conclusion as to beech would place it for purposes of control by forest management among Class III trees, especially if other Class I trees were removed from the stand. It should also be remembered, in this connection, that there is a wide range in susceptibility to gipsy-moth attack, not only between the species in Mosher's four classes, but also between the different species in each class.

Uneven-aged stands.—In uneven-aged stands a modified form of the selection system should be used, cutting to a diameter limit of approximately 12 to 14 inches, which limit, however, should not be strictly applied.

Of course, the same treatment can not be applied to even-aged and to uneven-aged stands. The stand now under discussion is of the latter form, which will be first considered.

The *selection system* may be briefly explained as follows: It is the reverse of the clear-cutting systems already described as applicable to stands like those at Dover, Exeter, Wareham, and Medfield. The whole area remains continually covered with trees which, when all ages and sizes are represented, mingled singly or in groups, are called a selection forest.[1] In the selection system of cutting and securing reproduction the cuttings are made annually or at longer intervals, the mature trees being selected and those not mature left. To maintain a stand indefinitely under this system it is essential that no more trees be cut than will equal in volume the growth of wood put on by the whole stand in the year or other interval between cuttings.

In managing old, uneven-aged stands which have not previously been under management, one of the first steps is to decide upon the approximate rotation to use, for example, 100 years, and then to remove as far as is possible, without making too large openings in the crown cover, all trees too large to be grown in that length of time.

In stands like the one under discussion it would be well to do this and also, in the first cutting, to eliminate red oak and reduce as much as is possible, with due regard to silvicultural considerations, paper birch and other intolerant species of Class I trees, which form a very small percentage of the stand and can not maintain themselves in stands with a large percentage of tolerant trees. The cuttings should each be accompanied by a thinning, removing all dead, dying, defective, or suppressed trees, regardless of their species, but leaving any the removal of which would expose the ground too much. The selection cuttings and thinning combined may remove as much as 50 per cent of the original stand, leaving about 200 trees per acre. In this stand the result upon each size class present is shown in the table on page 46. The result upon the representation of each species appears in the following table.

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[1] See table, p. 46.

Stand and cutting table, North Berwick, Me. Northern hardwoods stand with no white oak.

Trees which control if in sufficient numbers.[1]	Original stand.			Number per acre left after cutting described on p. 44.
	Trees which control on this lot.	Other species present.	Number per acre.	
Class I:				
Red oak		Red oak	7	
Large-tooth aspen		Large-tooth aspen.	2	
Beech	Beech		182	77
		Paper birch	7	3
		Basswood	5	2
Class II:				
Hemlock	Hemlock		16	14
Class III:				
Red maple	Red maple		33	19
Sugar maple	Sugar maple		56	29
		Yellow birch	11	7
		Black birch	16	9
		Elm	(2)	(2)
	Hornbeam[1]		66	29
Class IV:				
White ash	White ash		5	5
		Black ash	(2)	
			406	194

[1] A list of controlling trees for the northern hardwoods region would differ from this one, prepared for the white-pine region. See hornbeam above.

[2] Less than one tree per acre.

For effective gipsy-moth control cleanings will be necessary for at least five years (see p. 29), but the expense may be greatly reduced by confining these to the sprouts of all Class I trees cut, excepting the beech, on which, as already stated, the gipsy moth is not likely to reproduce normally, unless beech is in mixture with other favored species.

Another method of controlling sprouts is to turn cattle into a lot to pasture. The practice of pasturing cattle in woodlots is followed by some owners wholly apart from any silvicultural considerations. It had been done on the lot now under discussion, with the result that it was almost entirely free of undergrowth of all kinds. Foresters condemn the practice, for cattle do not always discriminate between sprouts and seedlings or between valuable and worthless species, and the result is a loss of young growth desirable in any form of management and essential to the success of stands managed under the selection system. In stands containing a very large percentage of trees which are favored food of the gipsy-moth caterpillars, which it is desired to replace by planting, carefully regulated pasturing by cattle or by goats might control the hardwood sprouts, if done for several successive seasons after clear cutting and before planting, but there is danger of exposing the ground so much that it would dry out and entail a large loss among the trees when planted. It is not recommended. If done it should be on a small scale, experimentally.

In spite of the large size of some of the trees, the product of the first cutting will probably be chiefly cordwood, as the large trees in such lots are often hollow at the center. If they prove to be sound, and a mill is accessible, they would, of course, be put into logs for sawing. On this lot the actual product of such a cutting as the one just described was 20 cords of cordwood and 2,800 board feet of logs per acre, the whole equivalent to about 25 cords of cordwood.

If the stand remaining can fairly be described as a selection forest, that is, if all ages and sizes within the rotation and diameter limit adopted are sufficiently represented, management may be continued as it was begun on the selection system.

This was the case in the lot now under consideration, as is shown in the following table.

Stand at North Berwick, Me., typical of an unmanaged or natural-selection forest.

Diameter breast high.	Number of trees per acre alive.	
	Before cutting.	After cutting.
Inches.		
1	79	32
2	98	35
3	87	29
4	75	27
5	48	26
6	41	21
7	33	17
8	31	23
9	23	19
10	18	10
11	12	8
12	10	6
13	7	3
14	7	2
15	4	2
16	(1)	
17	1	(1)
18	2	(1)
19	(1)	
20	1	
21	1	
22	1	
23	(1)	
24	(1)	
25	(1)	
26	(1)	
27	(1)	
28		
29		
30		
31	(1)	
	579	260
Total[1]	4	1
Total stand	583	261
1 and 2 inches	177	67
Over 2 inches	406	194

[1] Less than one tree per acre of size indicated.

NOTE.—First cutting made to a diameter limit of approximately 12 to 14 inches, which was not strictly enforced. Stand also thinned at the same time to remove dead, dying, defective, and suppressed trees. Red oak eliminated.

It should be remembered that equal numbers in all size classes would not be a sufficient representation to make a many-aged stand a selection forest, in the sense that that term is used here, and that where suppressed trees have been removed equal sizes may be roughly accepted as an indication of equal ages, although a wide variation actually exists in these respects. To insure the perpetuation of a selection forest managed on the selection system there must be a much greater representation of the smaller than of the larger trees. Theoretically, if a rotation of 100 years is adopted and cuttings are planned to be made every 10 years, the trees should be divided into 10 classes, each of which should occupy one-tenth of the available ground area and crown space.

In stands other than that now under consideration, it might well happen that the stand remaining after the cuttings and thinning had been made could be described better as an even-aged than as a selection forest. The representation of trees in the smaller size classes might be much more even aged than that of the trees in the larger size classes which were removed and which gave it originally the characteristics of a selection forest. This is likely to be the case in stands which have been heavily pastured for a long period of years. In such cases the form of management should be changed from the "selection" system described above to the "shelter-wood" system.

Even-aged stands.—In even-aged stands, whether occurring naturally or produced by the management of uneven-aged stands as suggested above, the shelter-wood system may be used with a rotation of 70 to 100 years. The *shelter-wood system* somewhat resembles the system of successive cuttings, already described for other plots, except that the interval between cuttings is longer, natural reproduction instead of planting is depended upon to secure a new stand, and care is taken to maintain as nearly as possible a crown cover of uniform density over the whole area. This system is not likely to be practicable for stands of this kind in the immediate future. The essential principles of its application are to open the stand gradually in order to prevent too sudden exposure of existing young growth and to secure additional reproduction under the shelter of the old stand before it is wholly removed. The possibility of using it depends chiefly upon market conditions and logging costs. When these are most favorable several cuttings are made, but under present American conditions not more than two cuttings are possible.

The first cutting is made about 20 years before the end of the rotation, removing about half of the original number of trees. After reproduction is secured and is well started, the remainder of the original stand is removed in a final cutting.

With the faster growing species, like white ash, basswood, and red oak, a rotation of 70 years may be used, but 100 years are needed for the slower growing hardwoods. Considering the species which must be favored if the object is gipsy-moth control. a rotation of 100 years would be necessary.

Planting.—In the northern hardwoods region, of which this stand is typical, the greater part of the woodland must be kept growing hardwoods for many years to come. Where intensive methods are possible, the more poorly stocked areas may be changed from hardwood to coniferous stands.

The desirability of this change from the standpoint of gipsy-moth control will depend in each case upon the composition of the actual stand under consideration.

The change can be made best by planting, which it is believed has already been sufficiently considered in the discussion of other stands.

In view of its freedom from attack by the white-pine blister rust it is desired to emphasize the increased importance of red, or Norway pine for planting in the region infested with the gipsy moth.

CONCLUSIONS.

No single rule or simple formula can be given by which to secure in woodlands the control of the gipsy moth by forest management. Each lot and each combination of species presents a problem in which the controlling factors are site, soil, location, market, species present, their value and relative proportion, the degree of infestation, and the cost of labor.

In many cases these factors combine in such a way that management is economically impossible.

It is believed that the suggestions contained herein have been made so definite that a careful reading will enable any owner or other person interested in the problem to discriminate between results which may and those which may not reasonably be expected under certain conditions, which have been selected because typical of those on large areas within the infested region.

While we are waiting for definite results from the various experiments now in progress, some of which have been referred to in the preceding pages, it is well for foresters and entomologists squarely to face the fact that the possible field of forest management as a method of controlling the gipsy moth is strictly limited.

Even in the mixed hardwoods type, where success may in some cases reasonably be expected, the cost will often be prohibitive.

In other forest types, and in the other forest regions within the area now infested by the gipsy moth, general control by forest management may or may not prove to be an economic possibility.

Throughout the infested region much may be expected from outbreaks of the wilt disease and the gradual subsidence of the gipsy moth to a normal place among other injurious insects.

To control the moth in many of the stands of the mixed-hardwoods type of the white-pine region, spraying and creosoting must be used, while birds, parasites, and insect enemies must do their part.

In severe infestations forest management may be less expensive than spraying and creosoting and has the advantage of being constructive instead of merely palliative, but it can not be recommended as a method of relief for general indiscriminate application by States, cities, towns, and private owners of woodlands throughout the infested region.

APPENDIX.

SPECIES WHICH ARE NOT CONTROLLING TREES IN THE WHITE-PINE REGION.

CLASS I.—*Favored food of gipsy-moth larvæ in all stages.*

Ash, Mountain.[1, 2]
Balm of Gilead.[1]
Basswood.[1]
Birch, Paper.[3]
Birch, River.[1, 2]
Boxelder.[1, 2]
Oak, Bur.[1]
Oak, Chestnut.[1]
Oak, Pin.[1]
Oak, Post.[1]
Oak, Swamp white.[1]
Service Berry.[2, 4]
Sumac, Dwarf.[2, 4]
Sumac, Staghorn.[2, 4]
Tamarack.[1]
Willow, Glaucous.[1, 2]
Witch Hazel.[1, 2]

CLASS II.—*Favored food after earlier stages.*

Pine, Red.[3]
Spruce, Black.[1]
Spruce, Red.[1]
Spruce, White.[1]

CLASS III.—*Not particularly favored food.*

Birch, Black.[1]
Birch, Yellow.[1]
Beech, Blue.[2, 4]
Cherry, Black.[1]
Cherry, Choke.[2, 4]
Cherry, Wild Red.[2, 4]
Cottonwood.[1]
Elm, American.[3]
Elm, Slippery.[1]
Gum, Black.[3]
Hickory, Bitternut.[1]
Hickory, Mockernut.[1]
Hickory, Pignut.[3]
Hickory, Shagbark.[3]
Hop Hornbeam.[2, 4]
Maple, Silver.[1]
Poplar, Silver.[1]
Sassafras.[1, 2]

CLASS IV.—*Unfavored food.*

Arborvitæ.[1]
Ash, Black.[3]
Ash, Red.[1]
Balsam Fir.[2]
Butternut.[1]
Dogwood, Flowering.[2, 4]
Hackberry.[1]
Holly, American.[4]
Laurel, Mountain.[2, 4]
Locust, Black.[1]
Locust, Honey.[1]
Maple, Mountain.[2, 4]
Maple, Striped.[2, 4]
Mulberry, Red.[1]
Sheepberry.[2, 4]
Sycamore.[1]
Tulip.[1]
Walnut, Black.[1]

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE ON THE GIPSY MOTH.

1. FARMERS' BULLETINS.

No.

275. The Gipsy Moth and How to Control It. L. O. Howard, 1907. 22 pages, illus. (Superseded by No. 564.)

453. Danger of General Spread of the Gipsy and Brown-tail Moths through Imported Nursery Stock. C. L. Marlatt, 1911. 22 pages, illus.

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[1] Occurs infrequently.

[2] Of low value.

[3] A few stands in the region may be found where this species is sufficiently represented to require consideration in making plans of management.

[4] Always small in this region.

No.

564. The Gipsy Moth and the Brown-tail Moth, with Suggestions for Their Control. A. F. Burgess, 1914. 24 pages, illus.

2. BUREAU OF ENTOMOLOGY CIRCULARS.

58.[1] Report on the Gipsy Moth and the Brown-tail Moth, July 1904. C. L. Marlatt. 12 pages, 2 maps.

164. The Gipsy Moth as a Forest Insect, with Suggestions as to Its Control. W. F. Fiske, 1913. 20 pages.

3. BUREAU OF ENTOMOLOGY BULLETINS. NEW SERIES.

11. Gipsy Moth in America. Account of Introduction and Spread of *Porthetria dispar* in Massachusetts and of Efforts Made by the State to Repress and Exterminate It. L. O. Howard, 1897. 39 pages, illus., maps.

67.[1] Proceedings 19th Annual Meeting Association of Economic Entomologists, 1907. Pages 22–26. Occurrence of the Gipsy Moth in Connecticut. W. E. Britton.

87. Report on Field Work against Gipsy Moth. D. M. Rogers and A. F. Burgess, 1910. 81 pages, illus., map.

91. Importation into the United States of Parasites of the Gipsy Moth and the Brown-tail Moth. L. O. Howard and W. F. Fiske, 1911. 344 pages, illus.. maps.

101. Calosoma sycophanta: Its Life History, Behavior, and Successful Colonization in New England. A. F. Burgess, 1911. 94 pages, illus., map.

119. The Dispersion of the Gipsy Moth. A. F. Burgess, 1913. 62 pages, illus., map.

4. DEPARTMENT BULLETINS.

204. Report on the Gipsy Moth Work in New England. A. F. Burgess, 1915. 32 pages, illus., maps.

250. Food Plants of the Gipsy Moth in America. F. H. Mosher, 1915. 39 pages, illus.

251. The Calosoma Beetle (*Calosoma sycophanta*) in New England. A. F. Burgess and C. W. Collins, 1915. 40 pages, illus., map.

273. Dispersion of Gipsy Moth Larvæ by the Wind. C. W. Collins, 1915. 23 pages, illus., maps.

5. OTHER DEPARTMENTAL PUBLICATIONS.

Gipsy and Brown-tail Moths and their European Parasites. L. O. Howard. Yearbook of the Department of Agriculture for 1905. Pages 123 to 138, illus.

Wilt of Gipsy Moth Caterpillars. R. W. Glaser. Jour. of Agr. Research, 1915, Vol. IV, No. 2, pages 101 to 128, illus.

6. BUREAU OF ENTOMOLOGY BULLETINS, TECHNICAL SERIES.

12. Part VI.[1] A Record of Results from Rearings and Dissections of Tachinidæ. Charles H. T. Townsend, 1908. 24 pages, illus.

19. Technical Results from the Gipsy Moth Parasite Laboratory.
    - Part I. The Parasites Reared or Supposed to have been Reared from the Eggs of the Gipsy Moth. L. O. Howard, 1910. Pages 1 to 12, illus.
    - Part II.[1] Descriptions of Certain Chalcidoid Parasites. J. C. Crawford, 1910. Pages 13 to 24, illus.

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19. Technical Results from the Gipsy Moth Parasite Laboratory—Continued.
  Part III.[1] Investigations into the Habits of Certain Sarcophagidæ. T. L. Patterson. Introduction by W. F. Fiske, 1911. Pages 25 to 32.
  Part IV.[1] The Chalcidoid genus *Perilampus*, and its Relations to the Problem of Parasite Introduction. Harry S. Smith, 1912. Pages 33 to 70, illus.
  Part V.[1] Experimental Parasitism. A Study of the Biology of *Limnerium validum* (Cresson). P. H. Timberlake, 1912. Pages 71 to 92, illus.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE ON CONTROLLING TREES.

FOREST SERVICE BULLETINS.

No.

31. Notes on the Red Cedar. Charles Mohr, 1901. 37 pages, illus.
42. The Woodlot: Handbook for Owners of Woodlands in Southern New England. H. S. Graves and R. T. Fisher, 1903. 89 pages, illus.
53. Chestnut in Southern Maryland. Raphael Zon, 1904. 31 pages, illus.
63. Natural Replacement of White Pine on Old Fields in New England. S. N. Spring, 1905. 32 pages, illus., map.
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95. Uses of Commercial Woods of the U. S. I. Cedars (White Cedar, pp. 12–16) (Red Cedar, pp. 19–29). Wm. L. Hall and H. Maxwell, 1911. 62 pages.
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DEPARTMENT BULLETINS.

12. Uses of Commercial Woods of the U. S. Beech, Birches, and Maples. H. Maxwell, 1913. 56 pages.
152. The Eastern Hemlock (*Tsuga canadensis*). E. H. Frothingham, 1915. 43 pages, illus., map.
299. The Ashes: Their Characteristics and Management. W. D. Sterrett, 1915. 88 pages, illus., map.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE ON TREE PLANTING.

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29.[1] The Forest Nursery. Geo. B. Sudworth, 1900. 63 pages, illus.
45. The Planting of White Pine in New England. Harold B. Kempton, 1903. 40 pages, illus.
76. How to Grow and Plant Conifers in Northeastern States. C. R. Pettis, 1909. 36 pages, illus.

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13. White Pine under Forest Management. E. H. Frothingham, 1914. 70 pages.
153. Forest Planting in the Eastern United States. C. R. Tillotson, 1915. 38 pages, illus.

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FOREST SERVICE CIRCULARS.

No.
58. Forest Planting Leaflet. Red Oak (*Quercus rubra*), 1911. 4 pages.
60.[1] Forest Planting Leaflet. Red Pine (*Pinus resinosa*), 1907. 4 pages.
61. Forest Planting Leaflet. How to transplant forest trees, 1911. 4 pages.
67.[1] Forest Planting Leaflet. White Pine (*Pinus strobus*), 1907. 6 pages.
69. Forest Planting Leaflet. Fence post trees, 1907, 4 pages.
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106.[1] Forest Planting Leaflet. White Oak (*Quercus alba*), 1907. 4 pages.
195. Forest Planting in the Northeastern and Lake States, 1912. 15 pages, illus.

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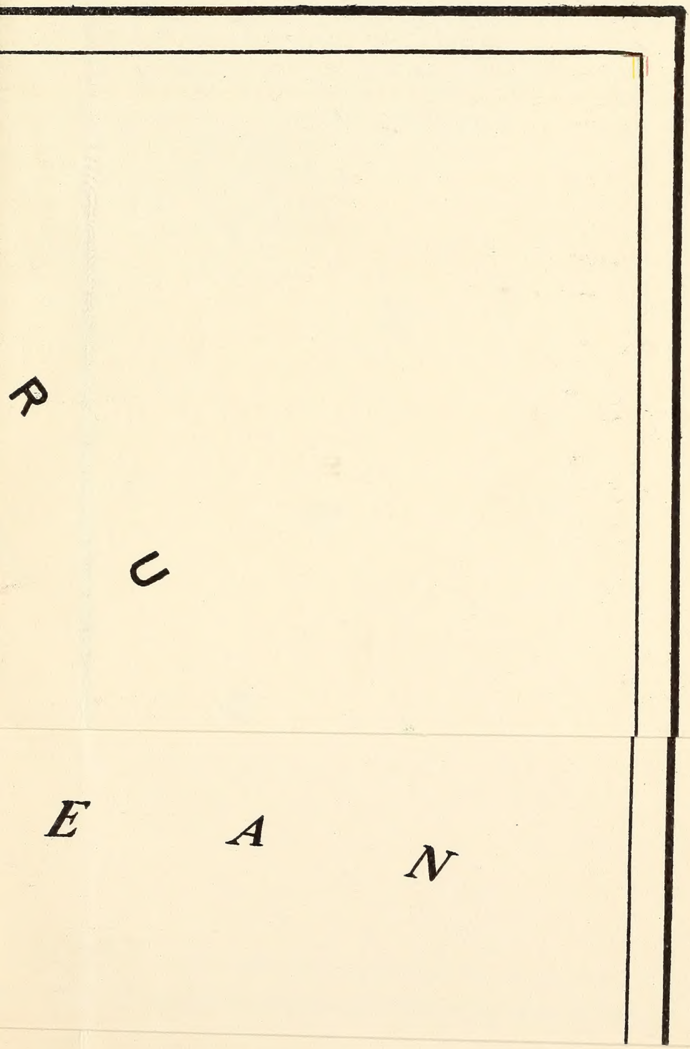

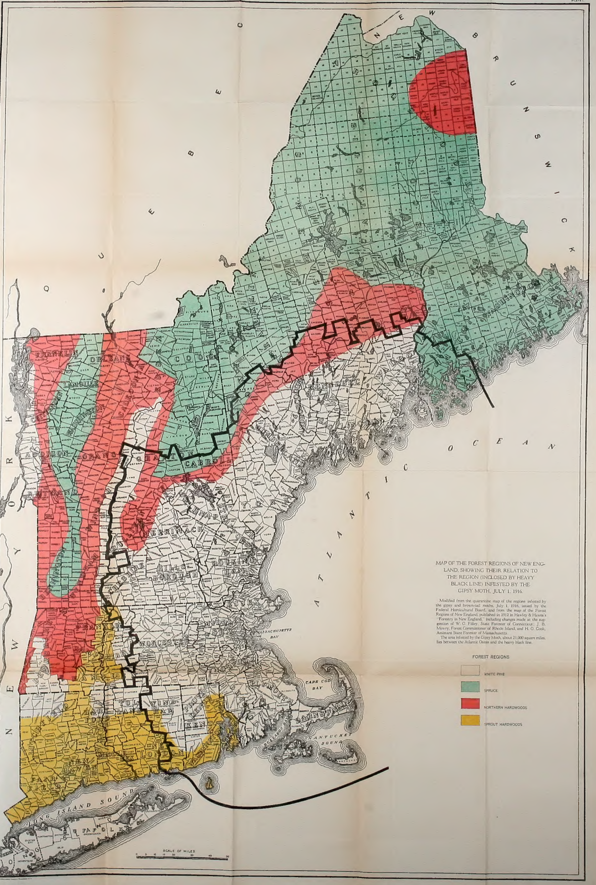

MAP OF THE FOREST REGIONS OF NEW ENGLAND, SHOWING THEIR RELATION TO THE REGION (INCLOSED BY HEAVY BLACK LINE) INFESTED BY THE GIPSY MOTH, JULY 1, 1916.

Modified from the quarantine map of the regions infested by the gipsy and brown-tail moths, July 1, 1916, issued by the Federal Horticultural Board, and from the map of the Forest Regions of New England, published in 1912 in Hawley & Hawes's "Forestry in New England," including changes made at the suggestion of W. O. Filley, State Forester of Connecticut; J. B. Mowry, Forest Commissioner of Rhode Island, and H. O. Cook, Assistant State Forester of Massachusetts.

The area infested by the Gipsy Moth, about 21,000 square miles, lies between the Atlantic Ocean and the heavy black line.

FOREST REGIONS

☐ WHITE PINE
🟩 SPRUCE
🟥 NORTHERN HARDWOODS
🟨 SPROUT HARDWOODS

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